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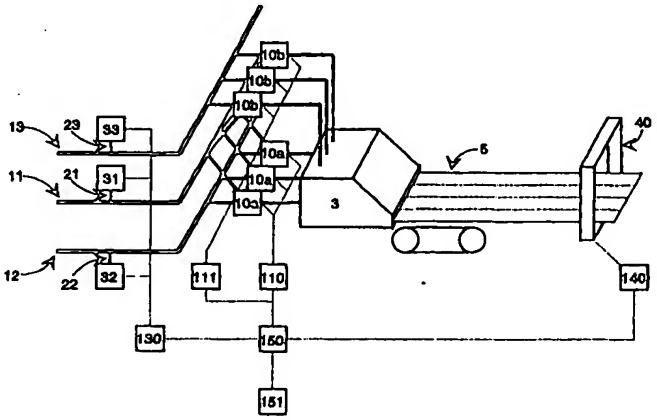

(57) Abstract

Method of controlling cross–direction property profiles of a paper web (5). The method employs a control system (150) for regulating a headbox (3) or headboxes (3a, 3b) of a paper machine. Said property profile or profiles is/are measured by a measurement system (40, 140). The measurement signal thus obtained is supplied to said control system (150). The headbox (3) or headboxes (3a, 3b) is/are supplied with at least two feed streams (11, 12) which contain feedstuffs for the paper suspended in aqueous solution. The feed streams are divided into feed zones in cross–machine sections of the headbox (3) or headboxes (3a, 3b). Said feed zones are each supplied with combinatory streams of said feed streams (11, 12; 11, 12, 13; 11, 12, 13, 14). A property, such as, concentration and/or consistency and/or brightness and/or color and/or equivalent, of one or more feedstuffs of said feed streams (11, 12; 11, 12, 13; 11, 12, 13, 14) is measured. The thus obtained measurement signal is fed to said control system (150). Based on said measurements of the property profile or profiles and based on said measurements of said property and based on setpoint values, control signals are formed. By means of them, an actuator (10) or an actuator combination (10a, 10b) situated at each of said feed zones of the headbox (3) or headboxes (3a, 3b) is regulated, by which actuator or actuator combination combinatory proportions of different feed streams (11, 12) supplied to the feed zone are affected to achieve a desired property profile or profiles of the web (5).

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Method and apparatus for control of a headbox in a paper machine

The invention relates to a method of controlling one or more cross-direction property profiles of a paper web manufactured by a paper machine, which method employs a control system for regulating a headbox or headboxes of a paper machine and in which method said property profile or profiles is/are measured by a measurement system, the measurement signal obtained from said measurement system being supplied to said control system, and which headbox or headboxes is/are supplied with at least two feed streams which contain feedstuffs for the paper to be manufactured suspended in aqueous solution and which feed streams are divided into feed zones in cross-machine sections of the headbox or headboxes, which feed zones are each supplied with combinatory streams of said feed streams.

In addition, the invention relates to an apparatus for controlling one or more cross-direction property profiles of a paper web manufactured by a paper machine, which apparatus comprises a control system for regulating a headbox or headboxes of a paper machine, a measurement system for measuring said property profile or profiles, means for feeding the measurement signal obtained from said measurement system to said control system, means for supplying at least two feed streams to the headbox or headboxes, which feed streams contain feedstuffs for the paper to be manufactured in aqueous solution, and means for dividing the feed streams into feed zones in cross-machine sections of the headbox or headboxes, which feed zones are each supplied with combinatory streams of said feed streams.

As is known in prior art, systems for controlling the cross-direction grammage of paper manufactured by paper machines operate in the following way. The flow of thickstock coming into a wire pit of a paper machine is regulated by a grammage valve based on grammage measurement at the dry end of the paper machine. The grammage of the paper web is measured by means of measuring sensors traversing

in a cross direction thereof, and the measurement result of the cross-direction grammage profile is averaged and passed as a feedback signal of a control system. The flow of thickstock is passed from the grammage valve, as known in prior art, to the wire pit, into which white water from the wire section of the paper machine is also passed. The thickstock flow and whitewater are mixed in the wire pit and the thus obtained diluted stock flow is passed, as known in itself, through pulp cleaning and deaeration devices to an inlet header of a headbox and therefrom further through a distribution tube bank of the headbox, possibly through an equalization chamber and a turbulence generator to a slice channel of the headbox. A pulp suspension jet is discharged from the slice channel onto a forming wire or into a forming gap between forming wires.

As is known in prior art, the cross-direction grammage profile of paper manufactured by paper machines is regulated by profiling the height of a slice opening in a headbox based on the aforesaid grammage measurement at the dry end of the paper machine. Recently, so-called dilution regulations have also become more common, comprising supplying dilution water, usually whitewater or a stock that is more dilute than the headbox stock, to individual feed points situated in the cross-direction in connection with a headbox. This dilution water feed system serves to profile the cross-direction grammage profile of a slice jet together with the regulation of a profile bar or without it. A special advantage of dilution regulation is that the headbox can be operated with a slice opening of a uniform height so that the cross-direction flows in the slice jet and after it, caused by the profiling of the height of the slice opening, as well as distortions of the fiber orientation profile of paper resulting from them may be avoided.

An object of the invention is to allow more accurate and faster control of properties of the paper web, by means of a novel method and arrangement of devices, and exploiting the benefits offered by them.

An object of this invention is to take advantage of several recent technologies in combination, including development of dilution headboxes, concentration measure-

ment devices suited to the paper industry, and the potential for advanced control strategies in modern control systems.

Prior-art dilution headboxes are subdivided into several feed zones across the headbox. Additionally, there may be more than one layer of such feed zones. Two or more streams of feedstuff supply each layer of feed zones, and each stream of feedstuff may supply one or more layers of feed zones. Each feed zone in each layer is equipped with means of controlling the combinatory proportions of streams fed to that feed zone, normally using a suitable valve arrangement. Additionally, there may be one or more layers of feed zones which are supplied by only one feed stream, or are supplied by plural feed streams without means of controlling combinatory proportions of feed streams fed to each feed zone.

Commonly, two feed streams are provided, one supplying the main feedstuff, and the other supplying a feedstuff of different properties. Normally, the second stream is more dilute than the main stream, but this need not always be so. The dilute feedstuff is normally whitewater taken from the wire pit or short circulation, often with some processing, such as deaeration, cleaning, or filtration. The main feedstuff also normally contains whitewater, to which a thickstock is added. In some cases, clarified water may be used instead of whitewater as the dilute feedstock.

More than two feed streams may be provided, where each feed stream supplies feedstuffs of different material composition. For instance both whitewater and clear water streams may be supplied as well as the main feedstuff stream; alternatively, two main feed streams may carry different feedstuffs, with a third feed stream carrying a dilute feedstuff. However, it is also possible that more than one stream contains the same feedstuff; in this case, all streams carrying an identical feedstuff are treated as a single consolidated stream for the purposes of this invention. Applicability of this invention requires that not all streams carry exactly the same feedstuff.

The streams fed to each feed zone are mixed together in any of several ways in the feed zone, producing an aggregate stream. The aggregate streams from all feed zones are merged, forming a single jet discharged across the whole headbox. There may be some mixing between streams in adjacent feed zones in this merging. An example of a dilution headbox is the Valmet Sym-Flo D™.

With respect to different details of structures of dilution headboxes and equivalent we refer to the *following patents and patent applications*: *FI-92229 (corres. EP-0633352 A1) and US-5560807.*

In some cases, multiple conventional (non-dilution) headboxes may be operated to form in combination a dilution headbox. This is possible if the headboxes do not all have the same feed streams, and there is a difference in composition between some of the feed streams to the individual headboxes. In this case, modulating the slice lip profiles has the effect of changing the combinatory proportions of the feed streams at each location across the web. However, the streams are not mixed, so the effect is similar to operation of a multilayer dilution headbox.

It should be noted that the feedstuffs used in the paper industry are of complex composition, containing many distinct material components suspended in an aqueous solution. The principal material components are fibers of different kinds, with properties which depend on the fiber source (Norway spruce, silver birch, Eastern hemlock, bagasse, kenaf, etc.), and pulping process used. Resins and synthetic polymers, as well as various clays, minerals (ash), and other inorganic material may be added. Substances such as dyes, brighteners, anti-brighteners, bleaches. and opacity agents may occur in quantities which have negligible effects on the weight, strength, or other material properties of the web, but which have major effects on color, brightness, opacity, and other optical properties of the web. There may also be solutes dissolved in the aqueous solution, affecting its pH and other chemical properties, thus modulating the effect of other feedstuff components on properties of the web.

As is known in prior art, in initially forming a paper web, the aqueous solution is drained through porous fabric (the "wire" of a forming section) into the wire pit, as whitewater, leaving much of the suspended material to substantially form the web. The whitewater at each section of the wire contains substantially the same suspended components as the suspension layer above it, but in lesser concentrations. Normally, whitewater is combined from all sections of the wire into a single stream. When several forming units are used, as in manufacture of a multilayer web, the whitewater streams from each forming unit may be kept separate in the process, or may be merged into a composite whitewater stream.

The fraction of each component suspended in the jet which remains in the web is referred to as the "retention" of that component. Different components can have greatly differing retentions, and the retentions of some components is affected by chemical properties of the aqueous suspension (such as pH), and by concentrations of other components (such as polymers). Thus, the whitewater varies in its component concentrations differently to the jet. Moreover, the retention of each component can vary differently with process conditions.

The retention of each component generally increases if the web is made heavier, but to different extents. Since a single property of the web such as weight may vary across the web, and since the composition of the jet can vary across the web, the retention of each component in the jet can also vary across the web. As the whitewater from the wire pit is a mixture of whitewater drained from all locations across the machine, the average retention can be inferred from concentration measurements in the feed streams to a headbox.

Some paper machines make only a few grades of paper, and employ substantially the same feedstuffs under substantially similar process conditions whenever a particular grade is being manufactured. Under these circumstances, each grade likely has a characteristic narrow range of retentions, and there is little variation in concentrations of the main feedstock or the whitewater.

More commonly, however, paper machines make a variety of grades from feedstuffs of divers properties, and adjust process conditions accordingly. Under these circumstances, retention of each component can vary greatly within a single grade, and across grades. Similarly, whitewater concentrations can vary differently for each component, both within and across grades. Large variations can occur over short times within a single grade.

Recycled fiber tends to be more variable in properties than new fiber, and its use is increasing in many paper machines. Use of a paper machine's repulped off-specification production (broke) varies from time to time, even in single grade machines.

Thus, the plural feed streams to a dilution headbox normally contain different concentrations of each feedstuff component. In general, the ratio of concentrations of a component in the several feed streams is different for each component. In particular, a whitewater feed stream will be relatively richer in solutes and fine suspended solids than in fibers, and relatively richer in short fibers than in long fibers, when compared to the main feed stream.

The physical and chemical properties of the major feedstuff components exhibit considerable variation. This is partly due to their natural origin, and partly due to variations in processing. These component variations, together with variation in blending of components to form a feedstuff, cause variation in the properties of feedstuffs. Variation in the operation of the short circulation of the paper machine can be a further cause of feedstuff property variation.

Until recently, it was labourious to perform more than a superficial laboratory analysis of concentrations and other properties of typical paper industry feed streams. Accordingly, paper mill laboratories measure only a total retention, and the practice in the paper industry is to treat retention as a single quantity. More sophisticated laboratory instruments are now available, but due to remoteness from the process and other practical concerns, analyses of headbox feed streams are infre-

quent. Moreover, a laboratory analysis is unlikely to be sufficiently timely for control purposes when retention is varying.

Devices which measure viscosity or freeness as an analogue of consistency (an aggregate concentration of suspended solids) have been available for many years, but have been of mediocre reliability and accuracy. The technology underlying such devices is also unsuited to low consistency regimes, such as those encountered in feed streams to the headbox. Accordingly, such devices have seldom been installed in headbox feed streams, and have not been employed previously in cross machine control of dilution systems.

Newer, more sophisticated measurement devices are suitable for continuously and rapidly measuring concentrations of low consistency streams. These are capable of measuring distinct component concentrations, or distinct aggregate concentrations of groups of components (such as total ash concentration or total fiber concentration) as well as, or instead of measuring the total consistency.

An example of such a concentration measurement device is the device marketed by the trademark Kajaani RM-200™.

In addition to concentration, instruments are available for on-line measurement of other feed stream properties such as color and brightness of a sample, and for measuring the distribution of fiber lengths in a sample.

Other factors, such as pH or temperature, may determine the extent to which a feedstuff property affects web properties. Devices for measuring pH, various solvated ionic species (as pNa, pK, etc.), or temperature are commonly available, including some suitable for use in headbox feed streams.

Many properties of the moving web can be measured during manufacture of paper. Commonly, a paper machine is equipped with a number of measurement devices which traverse the moving web at one or more locations on the paper machine.

Alternatively, an array of sensors may be deployed across the web, or stationary sensors may remotely measure properties across the web. Typical properties measured are basis weight, water weight, ash weight, caliper, gloss, brightness, opacity, fiber orientation, and strength. Some of these properties may be measured in greater detail, such as distinguishing between different species of ash (Al_2O_3, $CaCO_3$, SiO_2, TiO_2, etc.) or different resins. Other properties, such as dry weight, fiber weight or percent moisture may be derived from these measurements.

These web property measurements are made in each of several subdivisions of the web in the cross machine direction, presented as a "profile" across the web. With modern measurement systems, the web subdivisions may be less than 1 cm in width. A control system for regulating the plural values of such a profile property commonly provides a means for entering the desired shape of the profile. Moreover, there may be several properties, each with a different desired profile shape.

Moreover, properties of the suspension discharged from the headbox may be measured during formation of the web on the wire. Such measurements should also be construed as web property measurements in the context of this invention, provided a property is measured at plural locations in the cross machine direction.

The ability to control the combinatory proportions of feed streams at each feed zone allows properties of the web to be controlled during manufacture. A change in combinatory proportions at all feed zones across the headbox can affect one or more properties of the web at all locations across the web. A change in combinatory proportions at a single feed zone can affect one or more properties of the web over a portion of the web. The width of the affected portion of the web may not correspond to the width of the feed zone, and the effect may be unevenly distributed in magnitude or sign within the affected portion of the web. When more than one property is affected, the effect on each property may be differently distributed over portions of the web which may differ in width and location.

The effect on a material property of the web, such as ash weight, of changing the combinatory proportion of feed streams depends on the different concentrations within those streams of each component which influences that property.

The effect on other properties of the web, such as color or opacity, depends both on material properties of the feed streams, and on non-material properties, such as brightness. The retention of each feed stream component over the affected portion of the web may also affect the magnitude of the effect, and this retention may be influenced by several measurable properties of the feed streams, such as pH or temperature.

A control system can more effectively modulate the combinatory proportions of the feed streams if it can more accurately model the process effect of such modulation on each of the properties to be regulated. Such modelling requires that the appropriate feed stream properties are measured, and that the dependencies between feed stream properties and web properties be substantially known. Many such dependencies are common knowledge.

Since the plural feed streams to a dilution headbox contain different relative amounts of the various feedstuff components, and since each feedstuff component affects one or more web properties to various extents, it is evident that changing the combinatory proportions of the feed streams can have dissimilar effects on plural web properties.

For example, if a dilution headbox utilizes two feed streams, one carrying whitewater and the other carrying the main stock, the fiber in the web is supplied predominantly by the main stock stream, but the ash component may be supplied in similar degree by both streams. Thus, changing the combinatory proportions of the feed streams at one or more feed zones will clearly affect the web fiber and ash profiles differently.

Nowadays, control systems exist which can effectively modulate one or more cross machine actuator systems to regulate one or more property profiles. The regulation of web properties can be enhanced by providing suitable measurements of properties of the plural feedstreams to a control system, and utilizing a process model which relates changes in web properties to the combinatory proportions of feed streams and to the properties of the feed streams.

An example of such a control system is the system marketed by the trademark Valmet Damatic XD™.

Regarding prior-art control systems of a paper machine, reference is also made by way of example to *US Patent 5,381,341 (corres. EP Patent 0 401 188 and FI Laid-Open Publication 85731*.

The salient points of the above discussion can be summarized as :

- The plural feed streams to a dilution headbox contain different relative amounts of the various feedstuff components, and differ in other properties such as color, brightness, pH, temperature, etc.

- Each feedstuff component affects one or more web properties to various extents. Web properties are also affected by other properties of the feedstuffs, such as color, brightness, pH, temperature, etc.

- Changing the combinatory proportions of the feed streams can have tangible effects on plural web properties. The extent to which a web property is affected by a change in the combinatory proportions of feed streams depends on the properties of those feed streams.

- By deploying suitably accurate and reliable measurements of concentration or other pertinent properties of the feed streams to a dilution headbox, a control system

can better regulate one or more property profiles of the web, by modulating the combinatory proportions of the feed streams at each feed zone of a dilution headbox.

With a view to achieving the objectives stated above and those that will come out later, the method of the invention is mainly characterized in that a property, such as, concentration and/or consistency and/or brightness and/or color and/or equivalent, of one or more feedstuffs of said feed streams is measured and the thus obtained measurement signal is fed to said control system, and that, based on said measurement of the property profile or profiles and based on said measurements of said property, such as, concentration and/or consistency and/or brightness and/or color and/or equivalent, and based on setpoint values or equivalent, control signals are formed for regulating an actuator or an actuator combination situated at each feed zone of the headbox or headboxes, by which actuator or actuator combination combinatory proportions of different feed streams supplied to the feed zone in question are affected to achieve a desired property profile or profiles of the web.

The apparatus of the invention is mainly characterized in that the apparatus additionally comprises in combination the following means:

means for sampling continuously or at intervals each of two or more feed streams supplied to a headbox or headboxes;

means for measuring properties of said feed streams, such as, concentrations of constituents in and/or brightness of and/or color of said samples;

regulation means for regulating combinatory proportions of said feed streams at each of a plurality of feed zones of the headbox or headboxes in a cross direction thereof; and

means for supplying the measurements of properties of said feed streams or factors calculated therefrom to said regulation means responsive to one or more measured

properties of the paper web and modulating the aforesaid combinatory proportions to regulate the aforesaid properties of the paper web.

In this invention, means are provided for sampling, continuously or at intervals, the material in each of two or more of the feed streams to a headbox which is equipped with means for controlling combinatory proportions of those feed streams at each of plural feed zones across the headbox, and means are provided for measuring properties such as the concentrations of constituents in these samples, and means are provided for supplying those measurements or factors calculated therefrom to any regulatory means responsive to one or more measured properties of the web and modulating the aforesaid combinatory proportions to regulate the aforesaid properties.

The novelty of this invention is in the use of means of sampling two or more feed streams to a headbox which is so equipped, together with means of measuring properties such as the concentrations of constituents of those samples, together with means of supplying those measurements or factors calculated therefrom to a means of regulating properties of the web during manufacture.

The benefits of this invention include more effective modulation of the combinatory proportions of the feed streams by any regulatory means responsive to one or more properties of the web, where such means includes means for modulation of the combinatory proportions of the feed streams at each of several feed zones across a headbox. The importance of this benefit is greatest in situations where one or more of the feed streams undergoes, or is likely to undergo a change in concentration of one or more of its constituents, or a change in brightness or color, or a change in another measured property, such changes occurring either continuously or intermittently, and in divers amounts.

The feed stream property measurements are used to calculate the effective proportionality factors between changes in the combinatory proportions of the feed streams and changes in properties of the web which are influenced by these feed

stream properties and combinatory proportions. Such effective proportionality factors may be for changes in the average combinatory proportions of the feed streams across the headbox, and may also or alternatively be for changes in the local combinatory proportions in each feed zone of the headbox. Such effective proportionality factors may be for the change in the average of a property across the web, or for the local property at each of several subdivisions of the web across the machine, where such subdivisions normally correspond substantially to the feed zones, but may alternatively correspond to narrower or broader subdivisions of the sheet.

Normally, each feed stream to the headbox is sampled, or such streams are sampled as are combined to substantially form each feed stream. However, it is not necessary to measure each property in all feed streams, since it may be known that a particular property is negligibly present or invariant in some feed streams. Similarly, it is possible that some feed streams may be unsampled, and have no property measurements. For example, if a feed stream supplies fresh clear water, it is unnecessary to measure the amount of fibre present in the stream, since the stream is a priori known to contain none. Similarly, if a stream is formed by dosing a colorant of substantially known hue and intensity into a stream of substantially known color, and said dosing ratio is regulated and known, it is unnecessary to measure the color of the resulting stream, as its color can be calculated ab initio from known quantities.

Each means of sampling a stream may be situated at any convenient point in the stream. In the case that more than one means of measuring a concentration or other property is supplied with a sample from a stream, a means of sampling the stream may be provided for each means of property measurement, or a means of sampling the stream may be shared among several means of property measurement.

Normally, the sampled streams are the main stock stream and the dilution stream, or such streams as are combined to substantially form the main stock stream and the dilution stream, and each means of sampling a stream may be situated at any convenient point in the stream in the case that more than one means of measuring a

concentration or other property is supplied with a sample from a stream, a means of sampling the stream may be provided for each means of property measurement, or a means of sampling the stream may be shared among several means of property measurement.

Means for measuring concentration or other property may be one or more instruments attached permanently, periodically, or intermittently to a means for sampling a stream, or may be one or more instruments remote from the means for sampling the streams, and to which samples must be brought. Additionally or alternatively, means for sampling a stream may be integral to a means for measuring concentration or other property, including cases where the sampling of the stream takes place within the stream, by exposure within the stream of an element of the means for property measurement. Means for sampling the streams may be autonomous or manually operated, and a means for measuring properties of a sample may be autonomous or manually operated. Means for measuring sample properties may be a laboratory procedure, carried out manually or mechanically.

Each means of measuring concentration may be responsive to the individual concentration of one or more constituents of the sample of the stream, or may be responsive to one or more aggregate concentrations of combined constituents of the sample of the stream, or may be responsive to both individual and aggregate concentrations. The measured concentrations are commonly for constituents such as a particular fiber type or a particular chemical species, or aggregates of constituents such as total fiber or total ash content. Each means of measuring other properties may be responsive to one or more optical properties, such as brightness or color, or may be responsive to one or more thermal or mechanical properties, such as viscosity, or may be responsive to chemical properties, such as pH, or to other properties, such as conductivity or magnetic reluctance. In practice, a single instrument may provide measurements of several properties, which may include concentration, optical, electromagnetic, thermal, mechanical, and chemical properties.

In the following, the invention is described in detail with reference to some exemplifying embodiments of the invention illustrated in the figures of the accompanying drawing, to the details of which embodiments the invention is in no way narrowly limited.

Figure 1 schematically illustrates a simple embodiment of the invention.

Figures 2a, 2b, and 2c schematically illustrate some variant arrangements for parts of Figure 1.

Figure 3 schematically illustrates another embodiment of the invention, in which a third feed stream is supplied to the headbox.

Figure 4 schematically illustrates another embodiment of the invention, in which there are two layers of feed zones in the headbox, with independent modulation of combinatory proportions in each layer.

Figure 5 schematically illustrates another embodiment of the invention, in which the slice lip of a dilution headbox is modulated in conjunction with modulation of combinatory proportions of a feed stream at each feed zone.

Figure 6 schematically illustrates another embodiment of the invention, in which two dilution headboxes are supplied with two feed streams each, with their webs spliced together during manufacture.

Figure 7 schematically illustrates a variant on the embodiment depicted in Figure 1, in which the controlled web property profiles are measured at several locations in the paper machine, including a web measurement apparatus situated in the forming section.

Figure 8 schematically illustrates another embodiment of the invention, in which two conventional headboxes are supplied with different feed streams, with their webs spliced together during manufacture.

Figures 9, 10, 11, and 12 depict block diagrams for embodiments of the invention which comprise methods of regulating web properties.

Figures 13a, 13b, 13c, and 13d depict variations on certain parts of the embodiments shown in the preceding figures.

Figure 1 schematically depicts an embodiment of the invention where a dilution headbox 3 is provided with two feed streams 11 and 12. One stream 11 supplies a stock suspension, while the other 12 supplies a dilution medium. The two feed streams 11,12 feed each feed zone of the headbox 3 by means of a suitable valve arrangement 10. The valve means 10 of the feed zones to the headbox feed zones are regulated by a computer or other instrument 110 which can communicate with other computers or instruments. Each feed stream 11,12 is equipped with a stream sampling arrangement 21,22, and these stream sampling arrangements 21,22 are connected to concentration measurement devices 31,32 which measure one or more concentrations or other properties of the streams.

The feed stream property measurement devices 31,32 are connected to a computer or other instrument 130 which can communicate the measured properties or factors calculated therefrom to other computers or instruments. The headbox discharge forms the paper web 5, which moves along the machine. A measurement device 40, commonly a frame with a traversing sensor platform, situated on the machine measures one or more properties of each subdivision of the web 5 as it passes the device 40. This device 40 is connected to a computer or other instrument 140 which can communicate with other computers or instruments. A control system 150 communicates with the feed zone regulating computers or instruments, with the stream property measurement computers or instruments 130, and with the web 5 property measurement computers or instruments 140. The control system 150

regulates one or more web 5 property profiles supplied by the web 5 measurement system 140 by modulating the combinatory proportions of the two feed streams 11,12 at each feed zone, by means of the actuation system 110, and employs in its control calculations the feed stream property measurements or factors calculated therefrom, supplied by the stream measurement system 130 for both of the streams 11,12. Means 151 are normally provided to furnish information from the control system to human operators, and for the operators to enter commands and setpoint values to the control system.

The number of feed zones may be greater than three, and the feed zones may be of equal or unequal capacity and characteristics. It is not necessary for all means of combining flows to be identical, and not all need be modulated by the web property profile regulator, provided at least three are so modulated. The various measurement and control systems may be embodied in a greater or lesser number of elements than shown. There may be plural means 151 for interaction with human operators, or none, and when such plural means are employed, they may be similar or dissimilar.

Note that the number of feed zones shown in Figure 1 is three, but the embodiment includes greater numbers of feed zones, of equal or unequal flow capacity and evenly or unevenly distributed across the headbox. Note that the salient functions of the various systems may in practice be combined in a lesser number of distinct units, or divided among a greater number of units. Note that the concentrations or other properties of the feed streams are used in the control calculations for regulating web properties by modulating combinatory proportions of feed streams in each feed zone of the headbox 3.

Figure 2a schematically depicts a simple variation of the embodiment presented in Figure 1, and described above. In this variant, a feed stream has two sampling arrangements 21,26, each with a single device for measuring stream properties 31, 36. These devices 31,36 are connected to a computer or other instrument 130 capable of communicating with other computers or instruments. The control system 150 employs in its control calculations the feed stream property measurements or

factors calculated therefrom, supplied by the stream measurement system 130 for all three of the stream measurement devices 31,32,36.

Figure 2b schematically depicts a simple variation of the embodiment presented in Figure 1, and described above. In this variant, both feed streams 11,12 have two sampling arrangements 21,22,26,27, each with a single device for measuring stream properties 31,32,36,37. These devices are connected to a computer or other instrument 130 capable of communicating with other computers or instruments. The control system 150 employs in its control calculations the feed stream property measurements or factors calculated therefrom, supplied by the stream measurement system 130 for all four of the stream measurement devices 31,32,36,37.

Figure 2c schematically depicts a simple variation of the embodiment presented in Figure 1, and described above. In this variant, two property measurement devices 35, 36 are connected to one of the sampling arrangements 26. These devices are connected to a computer or other instrument 131 capable of communicating with other computers or instruments. The control system 150 employs in its control calculations the feed stream property measurements or factors calculated therefrom, supplied by both stream measurement systems 130,131 or the four stream measurement devices 31,32,35,36.

Figure 3 schematically depicts a variation of the embodiment presented in Figure 1, and described above. In this embodiment, three feed streams 11,12,13 are fed to each feed zone of the headbox, and each feed zone of the headbox 3 has means 10 suitable for modulating the flow proportions from the three feed streams 11,12,13. A sampling arrangement 23 for the third stream 13 is connected to a feed stream property measurement device 33, which is connected to a computer or other instrument 130 capable of communicating the measurements to other computers or instruments. The control system 150 regulates one or more profiles supplied by the web measurement system 140 by modulating the combinatory proportions of the three feed streams at each feed zone of the headbox 3, by means of the actuation system 110, and employs in its control calculations the feed stream property

measurements or factors calculated therefrom, supplied by the stream measurement system 130 for each of the three streams 11,12,13.

The control system 150 regulates one or more profiles of the web 5 supplied by the web 5 measurement system 140 by modulating the combinatory proportions of the three feed streams (11,12,13) at each feed zone by means of the actuation system 110, by employing in control calculations the concentration measurements or factors calculated therefrom, supplied by the stream measurement system 130 for each of the three streams (11,12,13).

Figure 4 schematically depicts a variation of the embodiment presented in Figure 1, and described above. In this variant, three feed streams 11,12,13 are fed to a dilution headbox 3 equipped with two layers of independently modulated feed zones. One feed stream 13 supplies the upper layer only, another 11 supplies both layers, and the third 12 supplies the lower layer only. The combinatory proportions in each feed zone in each of the two layers of feed zones of the headbox are modulated by means of suitable valve arrangements 10a,10b provided for each layer. The valve arrangements 10a,10b to the headbox feed zones in both layers are regulated by a computer or other instrument 110,111 capable of communicating with other computers or instruments. The control system 150 regulates one or more profiles supplied by the measurement system 140 by modulating the combinatory proportions of the feed streams at each feed zone of each layer, by means of their actuation systems 110,111, and employs in its control calculations the feed stream property measurements or factors calculated therefrom, supplied by the stream measurement system 130 for the three stream measurement devices 31,32,33. Additionally, the control system 150 may similarly modulate the combinatory proportions of layers, either of entire layers or of subdivisions of layers.

The number of feed layers may be greater than two, and not all layers need have a means of combining flows to their feed zones. Also, not all layers which have means of combining flows to their feed zones need be modulated by the web property profile regulator. The means of combining flows to feed zones in different layers

may be of equal or unequal capacity and characteristics. The number and character of feed zones and associated means may differ between layers, but at least one layer should have at least three means of combining flows, where such means are modulated by the profile regulator.

The embodiment of Figure 4 may be generalized to more than two layers, of equal or unequal characteristics. The number of feed streams to feed zones may differ between layers. Each feed stream may feed one layer or more than one layer. More than one feed stream may convey the same feedstuff, provided at least one layer of feed zones is supplied with two or more different feed streams.

Figure 5 schematically depicts a variation of the embodiment presented in Figure 1, and described above. In this embodiment, arrangements 15 are also provided for modulating the slice lip of the headbox 3 at plural locations across the web 5. The arrangement 15 for modulating the slice lip of the headbox is regulated by a computer or other instrument 115 capable of communicating with other computers or instruments. The control system 150 regulates one or more profiles supplied by the measurement system 140 by modulating the combinatory proportions of the feed streams at each feed zone of the headbox 3 by means of their actuation system 110, and by modulating the shape of the headbox slice lip by means of its actuation system 115, and employs in its control calculations the feed stream property measurements or factors calculated therefrom, supplied by the stream measurement system 130 for both of the streams 11,12.

In the embodiment of Figure 5 one or more property profiles can be regulated by the combined modulation of feed stream combinatory proportions and slice lip shape. Usually two or more property profiles are of interest, such as fiber orientation and dry weight or caliper.

Figure 6 schematically depicts a variation of the embodiment presented in Figure 1, and described above. In this embodiment, four feed streams 11,12,13,14 are fed to two dilution headboxes 3a,3b equipped with independently modulated feed zones,

where the webs 5a,5b produced by the headboxes 3a,3b are spliced into a single web 5 before the measurement device 40. Two feed streams 11,12 supply the lower headbox 3a only, and the other two feed streams 13,14 supply the upper headbox 3b only. The combinatory proportions in each feed zone in each of the two headboxes 3a,3b are modulated by means of a suitable valve arrangement 10a,10b for each headbox 3a,3b. The valve arrangements 10a,10b for the feed zones in each headbox 3a,3b are regulated by a computer or other instrument 110,111 capable of communicating with other computers or instruments. The control system 150 regulates one or more profiles of the web 5 supplied by the measurement system 140 by modulating the combinatory proportions of the feed streams at each feed zone of each layer, by means of their actuation systems 110,111, and employs in its control calculations the feed stream property measurements or factors calculated therefrom, supplied by the stream measurement system 130 for the four stream measurement devices 31,32, 33,34. Additionally, the control system 150 may similarly modulate the combinatory proportions of layers of headboxes 3a,3b, either of entire headboxes or of subdivisions of headboxes.

The number of headboxes may be greater than two, and not all headboxes need have a means of combining flows to their feed zones. Also, not all headboxes which have means of combining flows to their feed zones need be modulated by the web property profile regulator. The means of combining flows to feed zones in a headbox may be of equal or unequal capacity and characteristics. The number and character of feed zones and associated means may differ between headboxes, but at least one headbox should have at least one layer which has at least three means of combining flows, where such means are modulated by the profile regulator.

This embodiment may be generalized to more than two headboxes, of equal or unequal characteristics, where their webs are spliced together during manufacture. Each headbox may have its own forming section, or more than one headbox may be on the same forming section. For regulation of web property profiles, multiple headboxes are analogous to a single headbox with number and type of layers equal to the sum of the actual headbox layers.

Figure 7 schematically depicts a simple variation of the embodiment presented in Figure 1, and described above. In this variant, three web measurement devices 40, 41,42 are deployed at different locations on the paper machine, and each is connected to a computer or other instrument 140,141,142 which can communicate with other computers or instruments. The control system 150 regulates one or more profiles supplied by one or more of the web measurement instruments 140,141,142 by modulating the combinatory proportions of the two feed streams at each feed zone, by means of the actuation system 110, and employs in its control calculations the feed stream property measurements or factors calculated therefrom, supplied by the stream measurement system 130 for both of the streams 11,12.

The various measurement devices and systems may be embodied in a greater or lesser number of elements than shown. A web measurement device may be connected to more than one web measurement computer or instrument, and a web measurement computer or instrument may be connected to more than one web measurement device. A web measurement computer or instrument may be incorporated within a web measurement device.

Where means of measuring web property profiles are deployed at plural locations in the machine, each means may measure single or plural or all measured property profiles. Each measured property profile may be measured at single or plural or all means. Where plural means each measure plural web property profiles, each of the plural means may measure the same or a different plurality of web property profiles.

Figure 8 schematically depicts another embodiment of the invention, in which two conventional headboxes 3a,3b are supplied with different feed streams 11,12. The arrangements for modulating the slice lip of each headbox are regulated by a computer or other instrument 115,116 capable of communicating with other computers or instruments. The control system 150 regulates one or more profiles supplied by the web measurement system 140 by modulating the combinatory proportions of the feed streams at each feed zone of each layer of the headbox, by means of the slice lip actuation systems 15a,15b,115, and employs in its control

calculations the feed stream property measurements or factors calculated therefrom, supplied by the feed stream measurement system 130 for the feed stream property measurement devices 31,32. Additionally, the control system 150 may similarly modulate the combinatory proportions of headboxes, either of entire headboxes or of subdivisions of headboxes.

The number of headboxes may be greater than two, and not all headboxes need have a means of modulating their slice lips. Also, not all headboxes which have means of modulating their slice lips need be modulated by the web property profile regulator. The number of means of modulating the slice lip may be greater than three, and may be evenly or unevenly distributed across the slice lip, and may have equal or unequal capacity across the slice lip. The number and character of means of modulating slice lips may differ between headboxes, but at least one headbox should have at least three means of modulating its slice lip, where such means are modulated by the profile regulator.

The two conventional headboxes are, within the context of this invention, operated as if they formed a single dilution headbox, where modulating the shape of the slice lip on each headbox alters the profile of combinatory proportions of the two jets. This embodiment may be generalized to more than two headboxes, of equal or unequal characteristics, where their webs are spliced together during manufacture. For regulation of web property profiles, multiple conventional headboxes are analogous to a single dilution headbox with number and type of feed streams equal to the sum of the feed streams to the individual headboxes.

Figure 9 depicts another embodiment of the invention as a block diagram of a method for regulating a web property profile by modulating combinatory proportions of two streams to plural feed zones in a dilution headbox, which uses measurements of feed stream properties in its calculations. A property measurement is provided for each of the two feed streams m31, m32. These measurements are used in a calculation unit 230, to produce the effective proportionality factor p41 between changes in combinatory proportions of the two feedstreams and changes in the regulated web

property. The web property measured profile m41 and its setpoint profile s41 are supplied to a calculation unit 241 which produces the web property error profile e41. The proportionality factor p41 and the web property error profile e41 are used by the profile regulation means 210 to modulate its output s10, which is normally the combinatory proportion setpoint profile, or a profile of setpoints for such means as substantially determine the combinatory proportion profile.

Only the essential elements are shown in this block diagram. The proportionality factor calculation unit 230 may employ other measurements and factors in addition to those shown, as may be required for the process relation between the regulated web property and the feed stream properties. The proportionality factor p41 may be a single value effective across the whole headbox, or it may be a profile of values, each effective in one or more feed zones of the headbox, or it may be a matrix of values, each effective in one or more feed zones of the headbox and in some subdivisions of the web in the cross machine direction, where the number of rows in such matrix of values need not be the same as the number of columns. The proportionality factor p41 may be supplied directly by the feed stream property measurement means. The web property profile regulator 210 may employ other measurements and factors in addition to those shown. The web property profile error e41 calculation unit 241 may be contained within the regulator 210, and may utilize weighting factors or nonlinear operations in addition to a simple error calculation.

The operations performed within the regulator 210 may be any commonly known algorithms for profile regulation, including, but not limited to

i) an array of PID-type regulators, each governing a single feed zone or group of adjacent feed zones, with or without compensation for cross coupling between individual regulators,

ii) optimization of a penalty function formed by using nonlinear operations on the error profile, such as squaring and summation, where said penalty function may also include other nonlinear operations on other profiles such as the combinatory proportion profile, such inclusion being by means of weighted addition, and where said optimization involves minimization by

adjustment of the combinatory proportions of feed zones, and which optionally includes simulation of the resulting error profile,

iii) an array of controllers employing fuzzy logic techniques, each governing a single feed zone or group of adjacent feed zones, with or without compensation for cross coupling between individual regulators,

iv) an artificial neural network, with inputs from inter alia the error profile and outputs to combinatory proportions, where said network has been trained, or has the capability to train itself, to adjust its outputs so that its inputs are driven towards zero.

Such operations may additionally include any commonly known time domain compensation method for profiles, including but not limited to

i) an array of Smith predictors and variants thereon, including variants with provision for identification of model parameters for use in prediction,

ii) an array of Kalman filters.

Figure 10 depicts a variation of the embodiment presented in Figure 9, and described above. In this embodiment, a second web property profile measurement m42 and its setpoint profile s42 are supplied to a calculation unit 242 which produces a second web property error profile e42. The proportionality factor calculation unit 230 produces a second effective proportionality factor p42, which relates changes in the combinatory proportions of the two feed streams to changes in the second profile. Both proportionality factors p41, p42 and both web property error profiles e41, e42 are used by the profile regulation means 210 to modulate its output.

The calculation methods for the second web property error profile, and for the second effective proportionality factor may differ from those for the first. The operation of the profile regulating means may be modulated by use of weight factors or similar techniques, such that the regulation of one profile takes precedence over the other, or such that the regulation effects a compromise between regulation of one or the other.

Figure 11 depicts a variation of the embodiment presented in Figure 9, and described above. In this embodiment, a property measurement is provided for a third feed stream m33, and supplied to a calculation unit 230 which produces effective proportionality factors p41a, p41b, which relate changes in the combinatory proportions of the three feed streams to changes in the regulated profile. Both proportionality factors p41a, p41b and the web property error profile e41 are used by the web property profile regulation means 210 to modulate its outputs s10a, s10b, which are normally the combinatory proportion setpoint profiles, or profiles of setpoints for such means as substantially determine the combinatory proportion profiles.

Figure 12 depicts a variation of the embodiment presented in Figure 9, and described above. In this embodiment, a second property measurement is provided for each of the two feed streams m36, m37 and supplied to a calculation unit 230, which produces the effective proportionality factor p41, which relates changes in the combinatory proportions of the two feed streams to changes in the regulated profile. The calculation unit 230 uses the measurements of both properties in both feed streams to produce the effective proportionality factor p41.

Figure 13a schematically depicts a simple variation of the embodiment presented in Figure 9, and described above. In this variant, a means 215 is provided for converting a combinatory proportion setpoint profile s10 into setpoint profiles s15a, s15b for slice lips of two headboxes such that said combinatory proportion profile is achieved between two headboxes. Optionally, a means 225 may also be provided for calculating the prevailing combinatory proportion profile m10 from the measured slice lip profiles m15a, m15b. The means 215 and 225 may optionally employ additional measurements and factors in their calculations.

Figure 13b schematically depicts a simple variation of the embodiment presented in Figure 9, and described above. In this variant, the prevailing combinatory proportion profile m10 is also supplied to the web property profile regulation means 210, for use therein.

Figure 13c schematically depicts a simple variation of the embodiment presented in Figure 9, and described above. In this variant, the web property profile regulation means 210 modulates both the profile of combinatory proportions of the two feed streams s10, and the slice lip profile of the headbox s15. Optionally the prevailing slice lip profile m15 can be supplied to the web property profile regulation means 210, for use therein.

Figure 13d schematically depicts a simple variation of the embodiment presented in Figure 9, and described above. In this variant, the prevailing combinatory proportion profile m10 and the measured web property profile m41 are also supplied to the calculation unit 230 which may use them in calculating a profile or matrix of effective proportionality factors p41.

Other embodiments of the invention are the obvious permutations of the salient features described in these embodiments and their generalizations. For example, an immediately obvious generalization is the application of this invention to multi-layer machines with one or more dilution headboxes and one or more conventional headboxes.

In all of these embodiments, the measurement of concentrations or other properties of the feed streams allows calculation of effective proportionality factors between changes to combinatory proportions of feed streams and changes to property profiles at each subdivision of the web in the cross machine direction.

The accurate and timely calculation of such proportionality factors greatly enhances the potential effectiveness of a control system, since most control algorithms can use them advantageously. When feed stream concentrations change, the controller can adjust combinatory proportions of feed streams to the headbox feed zones to compensate for those changes before any adverse effects occur in the regulated properties of the web.

Furthermore, accurate knowledge of such proportionality factors allows more precise modulation of combinatory proportions of feed streams to the headbox feed zones. Since the effect of a modulation is accurately known, a controller can make exact rather than approximate control corrections, both in response to a process disturbance and in response to a change in target.

Example of Proportionality Factor

As one example, the effective proportionality factor between a web 5 property W (such as dry weight or ash weight), whose value is W_i at a subdivision i of the web in the cross machine direction, and the combinatory proportion K_j of two feed-streams to feed zone j of the headbox, where the constituent (such as total consistency or ash consistency) influencing the property has measured concentration C_D in the stream whose proportion is K_j, and measured concentration C_S in the stream whose proportion is $1\text{-}K_j$ may be calculated as :

$$\frac{\partial W_i}{\partial K_j} = \frac{R_{ji}\,(C_D\text{-}C_S)\,W_i}{C_D K_j + C_S(1\text{-}K_j)}$$

where R_{ji} is a coefficient indicating the degree of influence of feed zone j of the headbox over a property in subdivision i of the web. The formulation expressed above defines a matrix of proportionality values, each effective for a single headbox feed zone and a single subdivision of the web. Other formulations may be used to relate properties such as opacity, brightness, or color of the web to TiO_2 concentration in or brightness or color of the feed streams. Similarly, other formulations may be used to relate other properties of the web to pertinent properties of the feed streams.

Whereas in the embodiments and drawings described above, particular variants of the invention are depicted, it should be understood that the invention is not restricted to the variants presented. Its applicability extends to other combinations of the

features presented in the embodiments and drawings. Its applicability extends to obvious generalizations of the various particulars presented.

Whereas in the drawings and embodiments, references are made to a particular number of feed streams, and to particular combinations of feedstuffs in those feed streams, it should be understood that this invention is not restricted to the particulars presented. Its applicability extends to any number or arrangement of feed streams, provided they are fed to plural feed zones across the headbox with means of modulating their combinatory proportions at each feed zone, and to any set of feedstuffs supplied to a headbox in these feed streams. Its applicability extends beyond any particular arrangements of computers, communication lines, and other equipment which can vary freely between realizations of the invention.

Whereas in the embodiments and drawings, references are made to particular property profiles and to particular cross machine actuation systems (other than the feed stream proportion profile), it should be understood that this invention is not restricted to the particulars presented. Its applicability extends to regulation of any property profile or combination of property profiles. Its applicability extends to regulation of one or more profiles by means of modulating other cross machine actuation systems in addition to modulating the feed stream proportion profile.

Whereas in the embodiments and drawings, reference is generally made to a single headbox, it should be noted that the invention is not restricted to single headbox control configurations. The invention extends to multiple headbox arrangements, one or more of which is a dilution headbox with means of modulating combinatory proportions of two or more feed streams at each of plural feed zones, with concentration measurements of samples in plural feed streams to one or more such dilution headboxes. The invention extends to control of multiple dilution headboxes in concert, and to combinations of dilution headboxes and conventional headboxes.

The essence of this invention is not in the use of any particular formula in calculating effective proportionality factors for a means of regulating one or more properties

of the web, nor is it in the use of any particular means of regulating one or more properties of the web used in controlling the operation of the headbox. The essence of this invention is in the use of means of sampling two or more feed streams to a headbox as described above, with means of measuring properties of constituents of said samples, and in the use of the measured properties or factors calculated therefrom in any formulation used in any means of regulating properties of the web during manufacture, where such regulatory means modulate the combinatory proportions of the feed streams at several feed zones across the headbox.

The claims are presented in the following and the various details of the invention may vary within the inventive idea defined by said claims and differ from the disclosure given above by way of example only.

Claims

1. A method of controlling one or more cross-direction property profiles of a paper web (5) manufactured by a paper machine, which method employs a control system (150) for regulating a headbox (3) or headboxes (3a,3b) of a paper machine and in which method said property profile or profiles is/are measured by a measurement system (40,140), the measurement signal obtained from said measurement system being supplied to said control system (150), and which headbox (3) or headboxes (3a,3b) is/are supplied with at least two feed streams (11,12) which contain feedstuffs for the paper to be manufactured suspended in aqueous solution and which feed streams are divided into feed zones in cross-machine sections of the headbox (3) or headboxes (3a,3b), which feed zones are each supplied with combinatory streams of said feed streams (11,12; 11,12,13; 11,12,13,14), **characterized in** that a property, such as, concentration and/or consistency and/or brightness and/or color and/or equivalent, of one or more feedstuffs of said feed streams (11,12; 11,12,13; 11,12,13, 14) is measured and the thus obtained measurement signal is fed to said control system (150), and that, based on said measurement of the property profile or profiles and based on said measurements of said property, such as, concentration and/or consistency and/or brightness and/or color and/or equivalent, and based on setpoint values or equivalent, control signals are formed for regulating an actuator (10) or an actuator combination (10a,10b) situated at each of said feed zones of the headbox (3) or headboxes (3a,3b), by which actuator or actuator combination combinatory proportions of different feed streams (11,12) supplied to the feed zone in question are affected to achieve a desired property profile or profiles of the web (5).

2. A method as claimed in claim 1, **characterized in** that the measured and/or desired CD property profile/profiles of the paper web (5) to be manufactured is/are selected from the following group: grammage, ash weight, caliper, gloss, sheen, brightness, color, opacity, fiber orientation, strength, dry solids, per cent moisture and/or different components of ash weight, and/or different parametric representations of color, such as: i) reflectance spectrum; ii) transmittance spectrum; iii) hue,

chroma, value; iv) Hunter L, a, b; v) CIE L*, a*, b*; vi) CIE tristimulus, and/or different attributes of color, such as: i) whiteness; ii) lightness; iii) tint; iv) purity; v) dominant wavelength; vi) fluorescence index; vii) metamerism index.

3. A method as claimed in claim 1 or 2, **characterized in** that in the method one feed stream (11) is a main stock stream regulated in consistency and the other feed stream (12) is a dilution water stream, preferably a whitewater stream, the concentration and/or consistency of one or more constituents in said streams being measured.

4. A method as claimed in any one of claims 1, 2 or 3, **characterized in** that the method employs three different feed streams (11,12,13) which each supply each feed zone of the headbox (3) or headboxes (3a,3b) (Fig. 3).

5. A method as claimed in any one of claims 1, 2 or 3, **characterized in** that the headbox (3) is supplied with three different feed streams (11,12,13), two (12,13) of which feed streams supply different layers of the headbox (3) and the third (11) of which feed streams supplies both layers, and that the first-mentioned layers of the headbox are provided with arrays of actuators (10a,10b) of their own in their different feed zones for regulating combinatory proportions of said feed streams (11,12; 11,13) (Fig. 4).

6. A method as claimed in any one of claims 1, 2 or 3, **characterized in** that the method employs four different feed streams (11,12,13,14), of which two feed streams (11,12) supply one headbox (3a) and the other two feed streams (13,14) supply the other headbox (3b), that the different feed zones of both headboxes (3a,3b) are provided with their actuator systems (10a,10b) for regulating combinatory proportions of said feed streams, and that component webs (5a,5b) coming from said headboxes (3a,3b) are spliced into a combination web (5) whose cross-direction property profile or profiles are measured by the measurement system (40,140).

7. An apparatus for controlling one or more cross-direction property profiles of a paper web (5) manufactured by a paper machine, which apparatus comprises a control system (150) for regulating a headbox (3) or headboxes (3a,3b) of a paper machine and a measurement system (40,140) for measuring said property profile or profiles, and means for feeding the measurement signal obtained from said measurement system to said control system (150), and means for supplying at least two feed streams (11,12) to the headbox (3) or headboxes (3a,3b), which feed streams contain feedstuffs for the paper to be manufactured suspended in aqueous solution, and means for dividing the feed streams into feed zones in cross-machine sections of the headbox (3) or headboxes (3a,3b), which feed zones are each supplied with combinatory streams of said feed streams (11,12; 11,12,13; 11,12,13,14), **characterized in** that the apparatus additionally comprises in combination the following means:

means (21,22,23,24,25,26) for sampling continuously or at intervals each of two or more feed streams (11,12; 11,12,13; 11,12,13,14) supplied to the headbox (3) or headboxes (3a,3b);

means (31,32,33,34,35,36,130,131) for measuring properties of said feed streams (11,12; 11,12,13; 11,12,13,14), such as, concentrations of constituents in and/or brightness of and/or color of said samples;

regulation means (10; 10a,10b; 110,150; 110,111,150) for regulating combinatory proportions of said feed streams (11,12; 11,12,13; 11,12,13,14) at each of a plurality of feed zones of the headbox (3) or headboxes (3a,3b) in the cross direction thereof; and

means (130) for supplying the measurements of properties of said feed streams (11,12; 11,12,13; 11,12,13,14) or factors calculated therefrom to said regulation means (10; 10a,10b; 110,150; 110,111,150) responsive to one or more measured properties of the paper web (5) and modulating the aforesaid combinatory proportions to regulate the aforesaid properties of the paper web (5).

8. An apparatus as claimed in claim 7, **characterized in** that said feed streams (11,12) are arranged to supply each feed zone of the headbox (3) by utilizing a valve arrangement (10), and that said valve arrangement (10) is regulated by a computer or other instrument (110) capable of communicating with other computers or instruments.

9. An apparatus as claimed in claim 7 or 8, **characterized in** that the sampling arrangement (21,22) of each feed stream (11,12) is connected to devices (31,32) for measuring a concentration or equivalent, which devices are connected to a computer or other instrument (130) which communicates said concentrations or factors calculated therefrom to other computers or instruments.

10. An apparatus as claimed in any one of claims 7—9, **characterized in** that a feed stream has two sampling arrangements (21,26), each with a single concentration measurement device (31,36) connected to a computer or other instrument (130) communicating with other computers or instruments (Fig. 2a).

11. An apparatus as claimed in any one of claims 7—10, **characterized in** that two or more concentration measurement devices (35,36) are connected to one sampling arrangement (26), which measurement devices (35,36) are connected to a computer or other instrument communicating with other computers or instruments (Fig. 2b).

12. An apparatus as claimed in any one of claims 7—11, **characterized in** that the apparatus employs an arrangement (15) for modulating the slice lip of the headbox (3) at plural locations across the web (5), and that said arrangement (15) is regulated by a computer or other instrument (115) communicating with other computers or instruments (Fig. 5).

13. An apparatus as claimed in any one of claims 7—12, **characterized in** that said headbox (3) is a dilution headbox provided with two feed streams (11,12), one (11) of said feed streams supplying a stock suspension and the other feed stream (12) supplying a dilution medium.

14. An apparatus as claimed in any one of claims 7—12, **characterized in** that the apparatus comprises three feed streams (11,12,13) fed to each feed zone of the headbox (3) (Fig. 3).

15. An apparatus as claimed in any one of claims 7—12, **characterized in** that the apparatus comprises four feed streams (11,12,13,14) fed to two dilution headboxes (3a,3b) equipped with independently modulated feed zones, the webs (5a,5b) produced by said headboxes (3a,3b) being spliced into a single web (5) before its profile measurement device (40) (Fig. 6).

16. An apparatus as claimed in any one of claims 7—11, **characterized in** that the apparatus employs two conventional headboxes (3a,3b), which are supplied with different feed streams (11,12) and both of said headboxes are provided with an arrangement for modulating their slice lip, said modulating arrangement being regulated by a computer or other instrument (115,116) communicating with other computers or instruments (Fig. 7).

17. For use in a sheetmaking process, and especially in manufacture of a continuous paper web, an apparatus comprising in combination:

(i) a headbox equipped with at least one layer of at least three feed zones in the cross machine direction, where such feed zones are similar or dissimilar in capacity and other characteristics, and where, if there are plural such layers, the number, capacity, and character of zones in each such layer are similar or dissimilar to zones in other layers;

(ii) at least two feed streams supplied to each of at least three feed zones in at least one of the layers of feed zones in (i), and where, if there are plural such layers, not all layers need be supplied by a plurality of feed streams, and where, if more than one such layer is supplied with plural feed streams, that plurality are similar or dissimilar between such layers;

(iii) for at least one layer with plural feed streams in (ii), means of modulating the combinatory proportions of at least two of the feed streams to

each of at least three of the feed zones, or means of modulating such means as substantially determine those combinatory proportions;

(iv) for at least one layer with plural feed streams in (ii), means of sampling at least two of the feed streams for which means exist for modulating combinatory proportions in (iii);

(v) means of measuring one or more properties of at least two of the feed stream samples in (iv), and especially means for measuring concentrations of material components of those samples, or for measuring concentrations of aggregates of material components of those samples, or for measuring brightness or color of those samples, or for measuring chemical or thermal, or electromagnetic and/or mechanical properties of those samples;

(vi) means of measuring one or more properties of the web at plural locations in the cross machine direction, optionally with plural such means deployed at different locations along the machine, where such plural means measure the same or different singular or plural web properties, where said measurements of web properties include properties of the web which are inferred from plural such actual web property measurements;

(vii) means for regulating one or more of the web property profiles in (vi) by governing the means of modulating the combinatory proportions of at least one layer in (iii), and which employs the sample property measurements in (v) or factors calculated therefrom.

18. An apparatus as claimed in claim 17, where the means for sampling one or more the feed streams in claim 17 (iv) and a means for measuring one or more properties of such samples in claim 17 (v) are combined in means for measuring properties of the streams by exposure of a responsive element within the stream to a portion of the stream.

19. An apparatus as claimed in claim 17, with means for modulating the slice lip of the headbox at three or more locations in the cross machine direction, and where the means for regulating one or more web property profiles governs this means of modulation in addition to its other means of modulation in claim 17 (vii).

20. An apparatus as claimed in claim 17, where one or more means of measuring one or more web properties is deployed in the forming section of the machine, and which measures properties of the jet being discharged from the headbox or of the partially formed sheet at plural locations in the cross machine direction, and where such properties are treated as web properties for the purposes of claim 17 (vii).

21. An apparatus as claimed in claim 17, with one or more additional headboxes which are similar or dissimilar in capacity and characteristics, and which are similar or dissimilar to the headbox of claim 17 (i) in capacity and characteristics, and which may or may not be dilution headboxes, and where the sheets formed from plural headboxes are spliced together during manufacture to substantially form a single multi-layer web, and where the means for regulating one or more web property profiles optionally employs such means for modulating operation as are provided for some or all of the additional headboxes in addition to its other means of modulation in claim 17 (vii).

22. An apparatus as claimed in claim 21, where at least one of the additional headboxes, together with its feed streams, attachments and chattels, satisfies the features of claim 17 (i), (ii), (iii), and (iv), and where the means for regulating one or more web property profiles employs means of modulating combinatory proportions of feed streams in one or more such headboxes in addition to its means of modulation (vii) in claim 17 and its other means of modulation in claim 21.

23. For use in a sheetmaking process, and especially in manufacture of a continuous paper web, an apparatus comprising in combination:

(i) at least two headboxes, not all of which are supplied with feed streams of exactly the same properties, where such headboxes are of similar or dissimilar capacity and characteristics, and where the sheets formed thereby are spliced together during manufacture to substantially form a single multi-layer web;

(ii) for at least two of the headboxes in (i), means of modulating the slice lip at three or more locations in the cross machine direction, where such

means are similar or dissimilar in number and disposition of locations between headboxes;

(iii) for at least two of the headboxes for which means of modulating slice lips exist in (ii), means of sampling the feed streams or such streams as are substantially combined to form the feed streams;

(iv) means of measuring one or more properties of at least two of the samples in (iii), and means for measuring concentrations of material components of those samples, or for measuring concentrations of aggregates of material components of those samples, or for measuring brightness or color of those samples, or for measuring chemical or thermal, or electromagnetic and/or mechanical properties of those samples;

(v) means of measuring one or more properties of the web at plural locations in the cross machine direction, optionally with plural such means deployed at different locations along the machine, where such plural means may measure the same or different singular or plural web properties, where said measurements of web properties include properties of the web which are inferred from plural such actual web property measurements;

(vi) means for regulating one or more of the web properties in (v) by modulating the slice lips of at least two of the headboxes in (ii), and which employs the sample property measurements in (iv) or factors calculated therefrom.

24. For use in a sheetmaking process, and especially in manufacture of a continuous paper web, a method comprising the following steps in combination:

(i) measuring one or more properties of the web at plural locations in the cross machine direction, optionally measuring the same or different singular or plural web properties at plural locations along the machine, including calculation of measurements from plural actual web property measurements;

(ii) calculating one or more web property error profiles, each as a difference between a web property measured profile and its respective setpoint profile, optionally employing nonlinear operations and weight factors to the result of the difference calculation, where singular or plural weight factors are used for

each property, and where such operations and weight factors are similar or dissimilar for each web property profile;

(iii) modulating combinatory proportions of plural feed streams to at least three feed zones in each of one or more layers of feed zones in each of one or more dilution headboxes, where the modulation is optionally of such means as substantially determines the combinatory proportions of the feed streams;

(iv) measuring one or more properties of samples from two or more feed streams to a dilution headbox, and measurement of concentrations of material components of those samples, or measurement of concentrations of aggregates of material components of those samples, or measurement of brightness or color of those samples, or measurement of chemical or thermal, or electromagnetic and/or mechanical properties of those samples;

(v) calculating effective proportionality factors between changes in combinatory proportions of feed streams to a dilution headbox and changes in properties of the web, where such calculating employs the measurements from (iv), and optionally employs other measurements and factors, and where the effective proportionality factor between a change to combinatory proportion and a change to a web property are a single value, effective across the whole headbox, or a profile of values, each effective in one or more feed zones of the headbox, or a matrix of values, each effective in one or more feed zones of the headbox and in some subdivision of the web;

(vi) using the effective proportionality factors in (v) in a method for regulating one or more web property error profiles in (ii), which modulates the plural combinatory proportions of plural feed streams to one or more headboxes in (iii), optionally, the method of regulating web property error profiles incorporates, explicitly or implicitly, the calculation of effective proportionality factors in (v), in which case the method uses the feed stream sample property measurements.

25. A method as claimed in claim 24, where the method for regulating one or more web property profiles modulates the slice lip at three or more locations in the cross

machine direction of each of one or more headboxes in addition to its other means of modulation in claim 24 (vi).

26. A method as claimed in claim 24, where the method for regulating one or more web property profiles modulates such apparatus as is provided at plural locations in the cross machine direction on one or more additional headboxes in addition to its other means of modulation in claim 24 (vi).

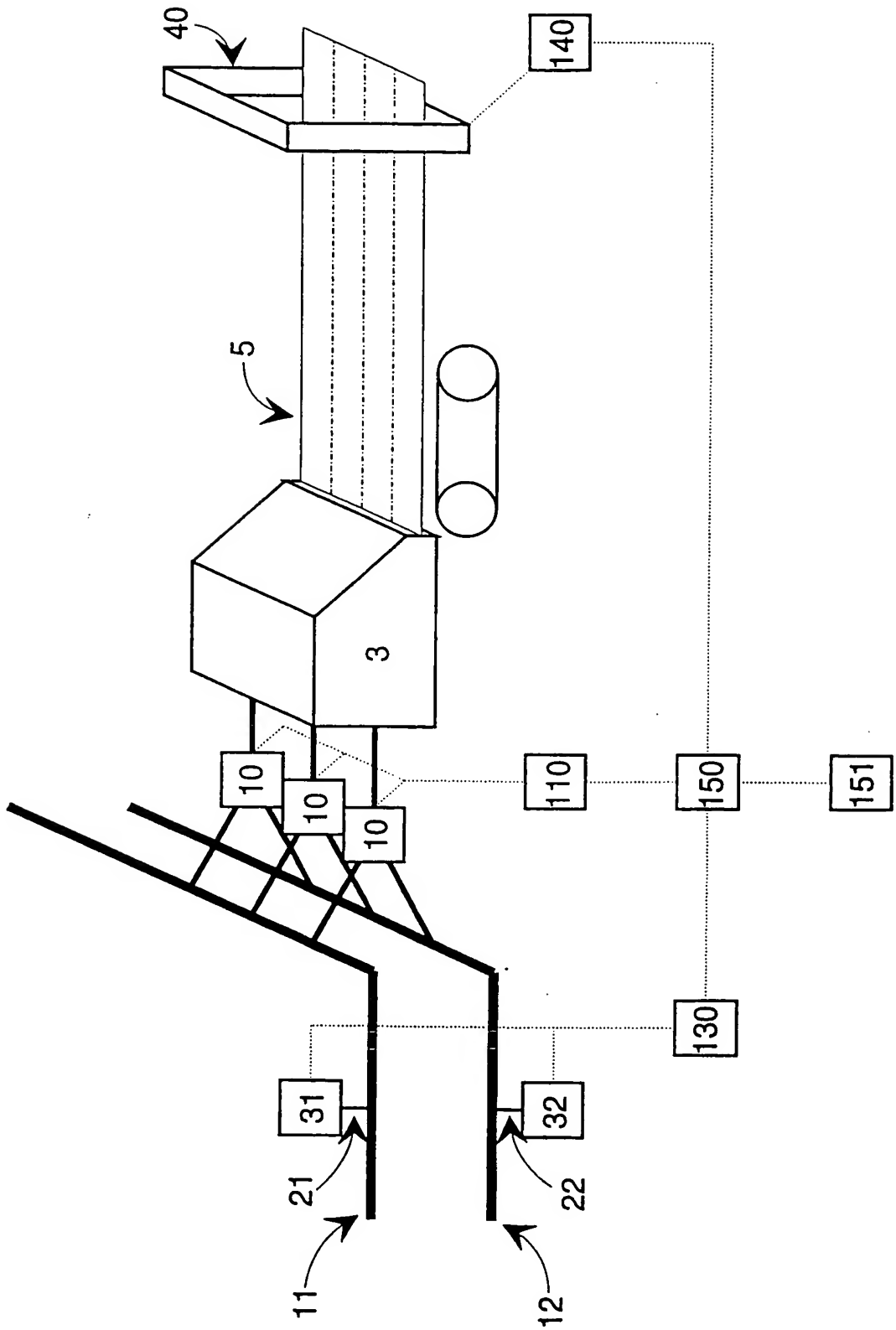

FIG. 1

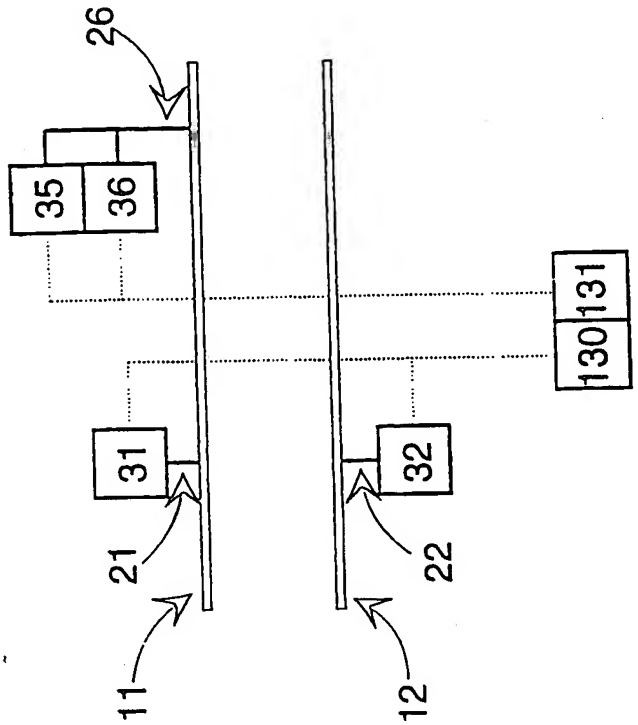

FIG. 2c

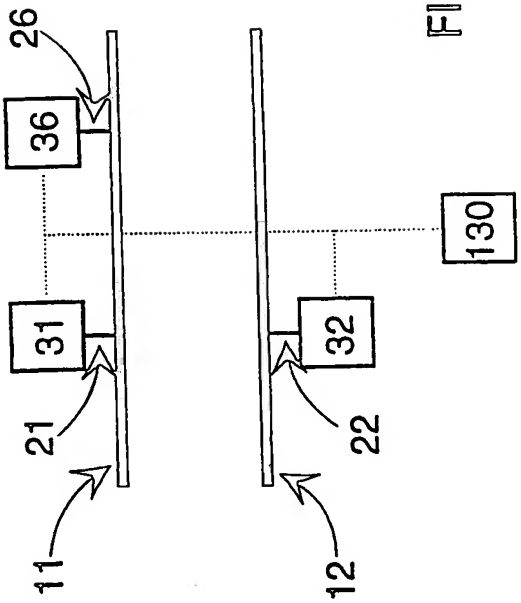

FIG. 2a

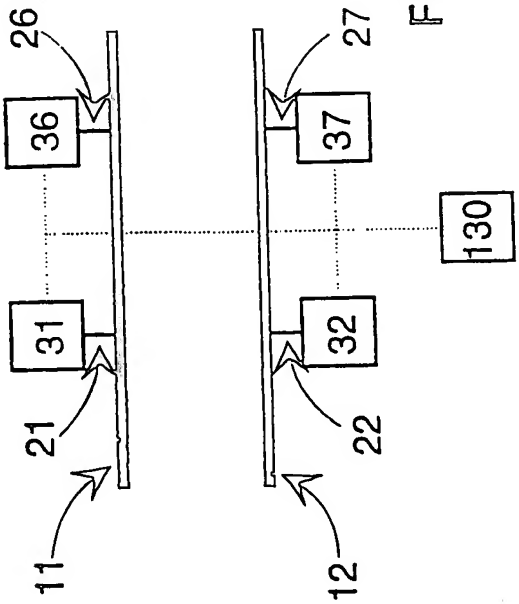

FIG. 2b

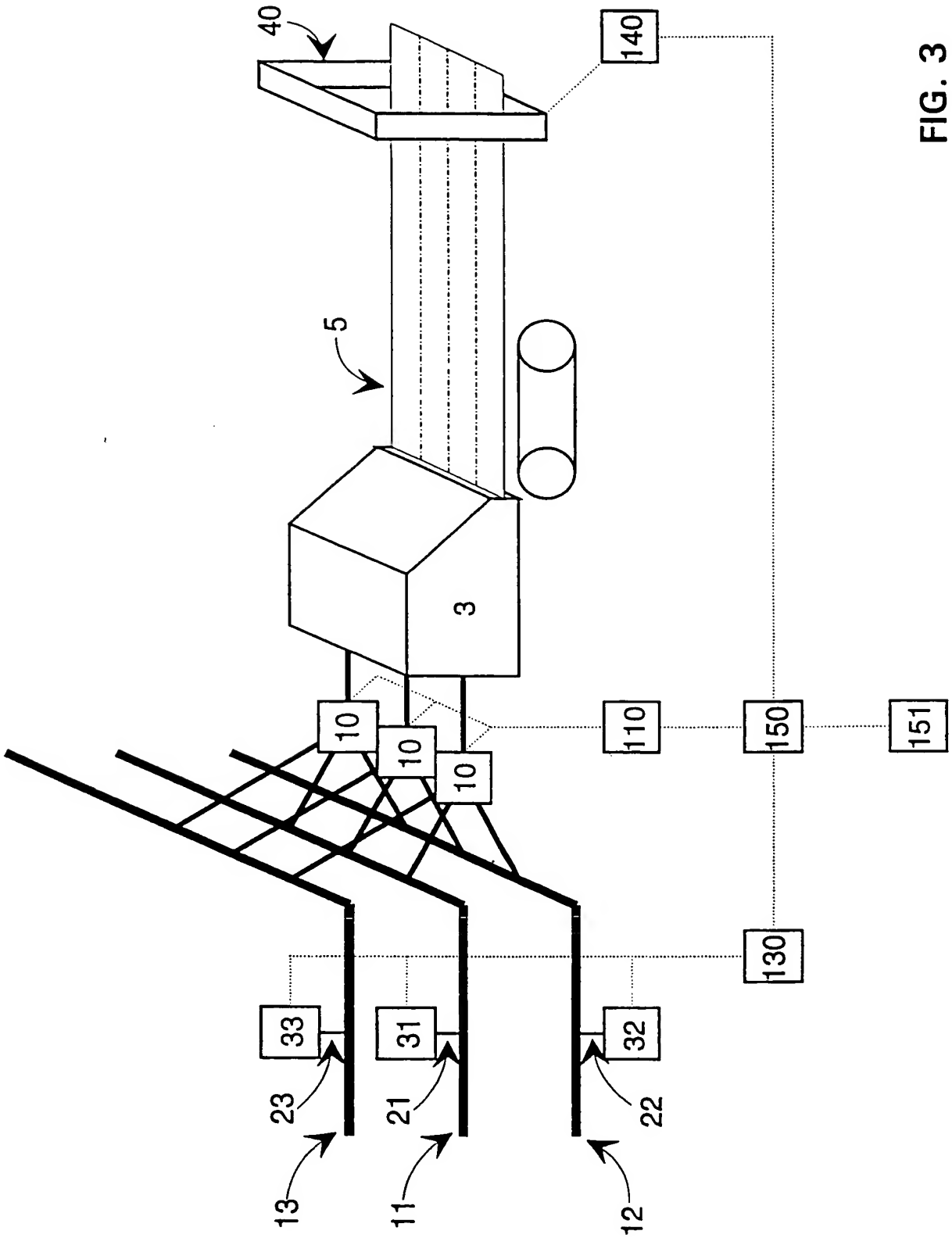

FIG. 3

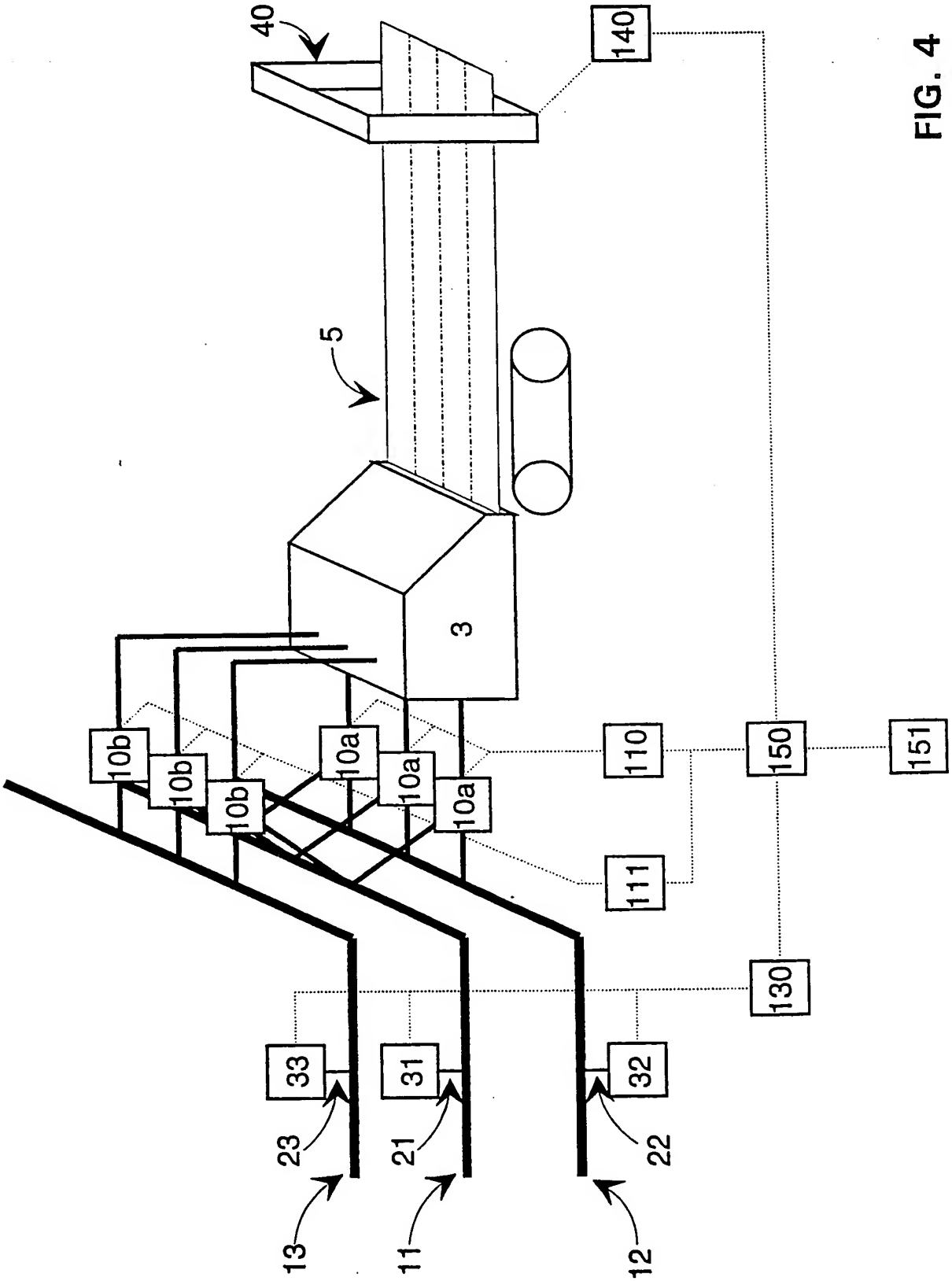
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FIG. 4

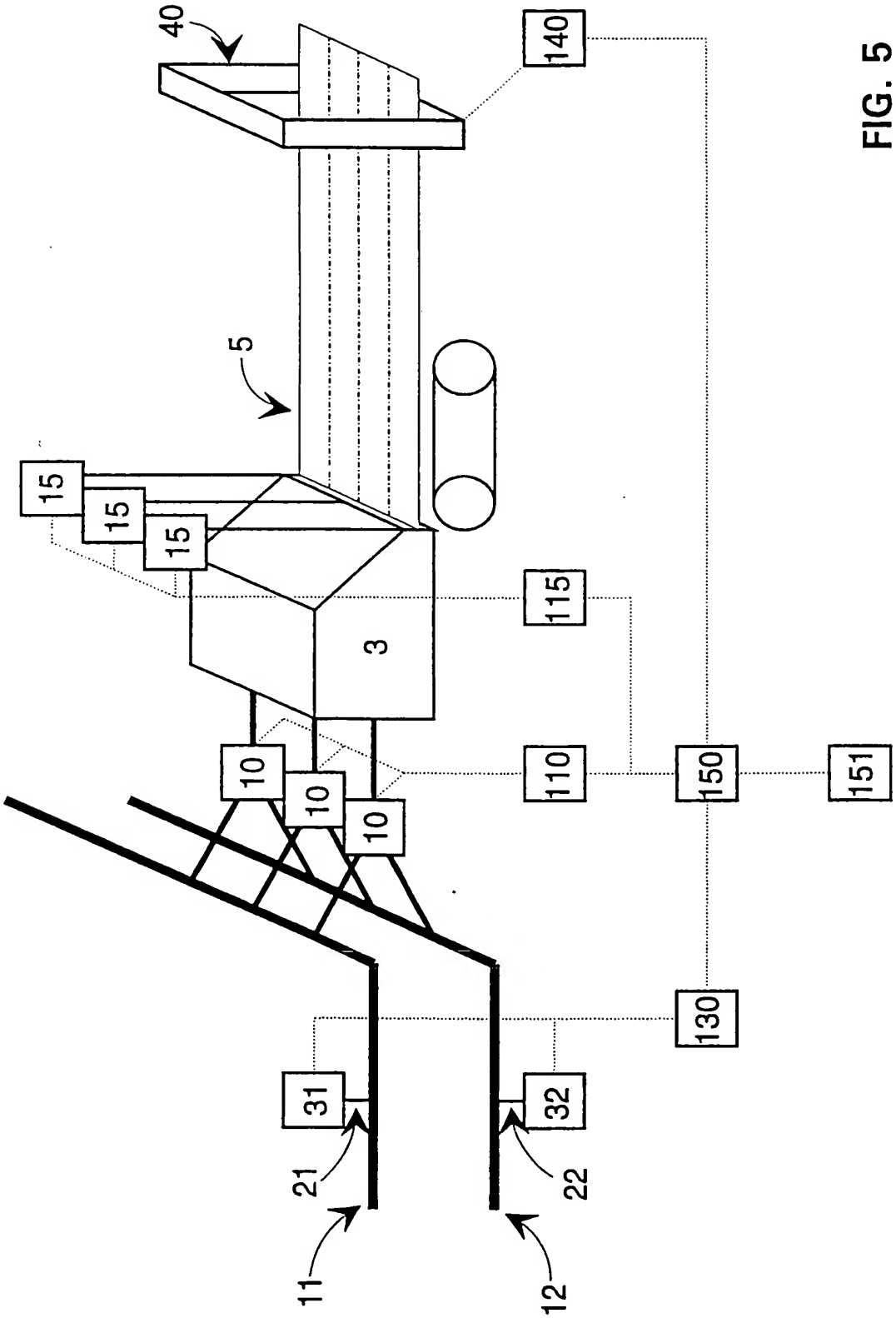

FIG. 5

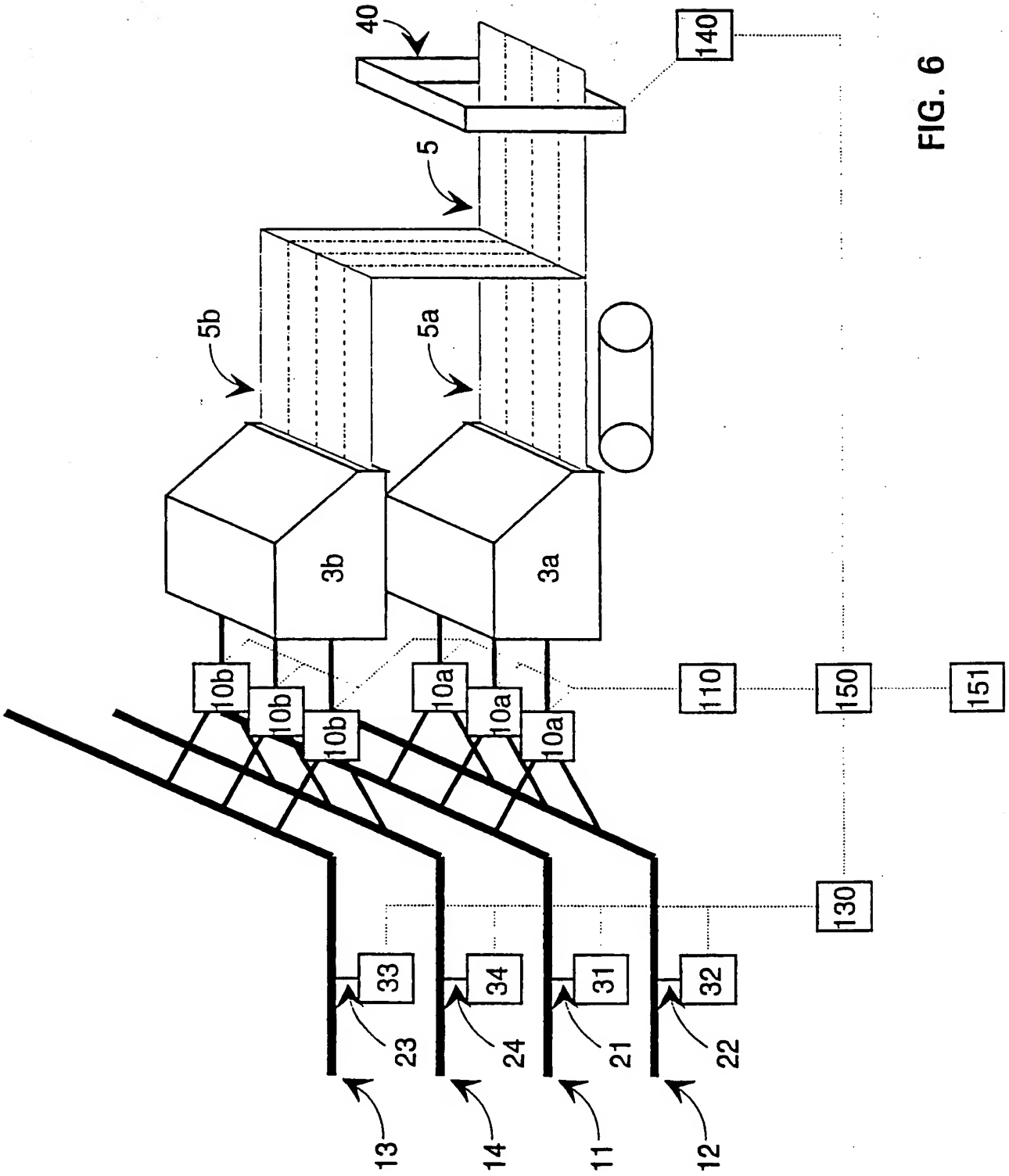
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FIG. 6

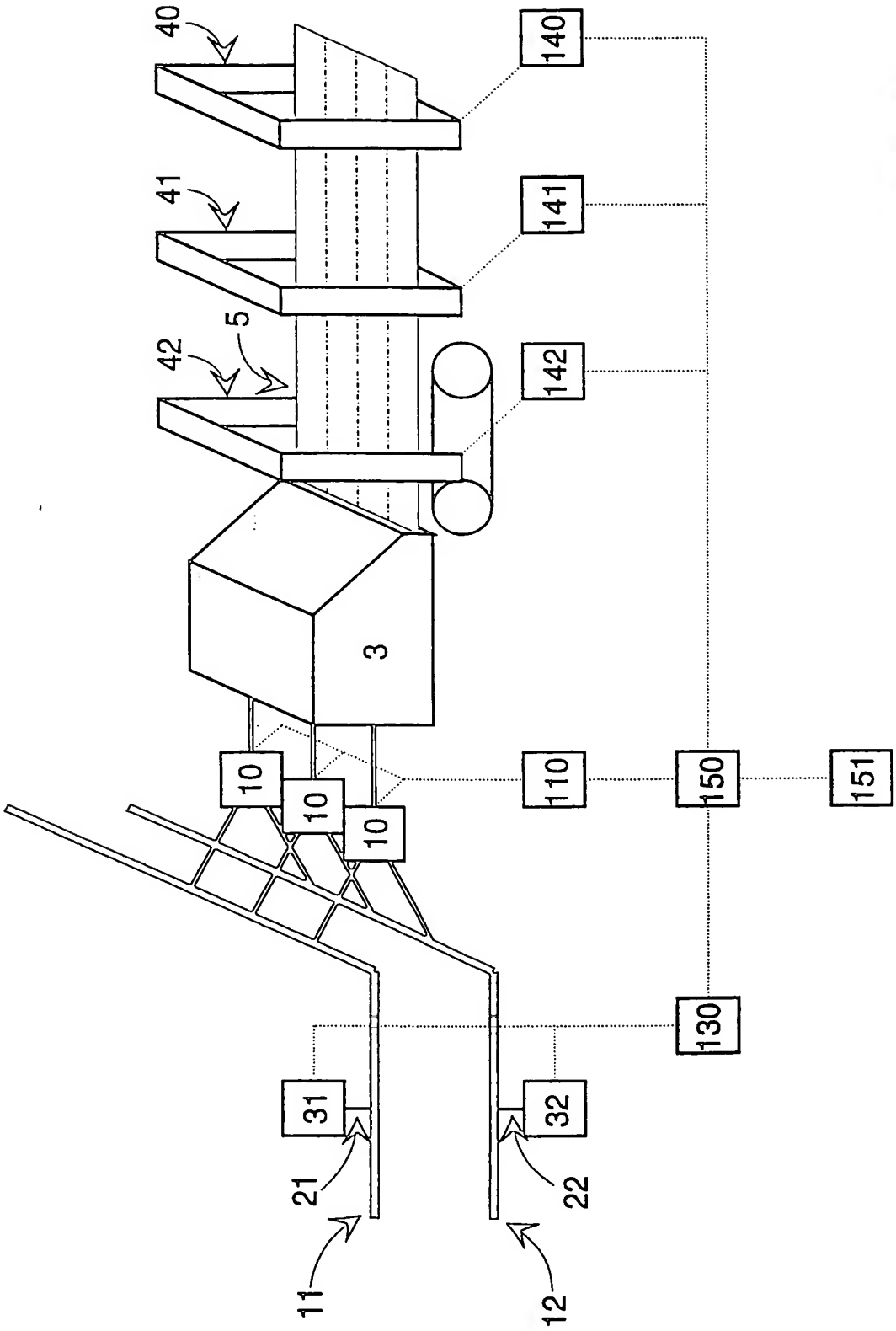

FIG. 7

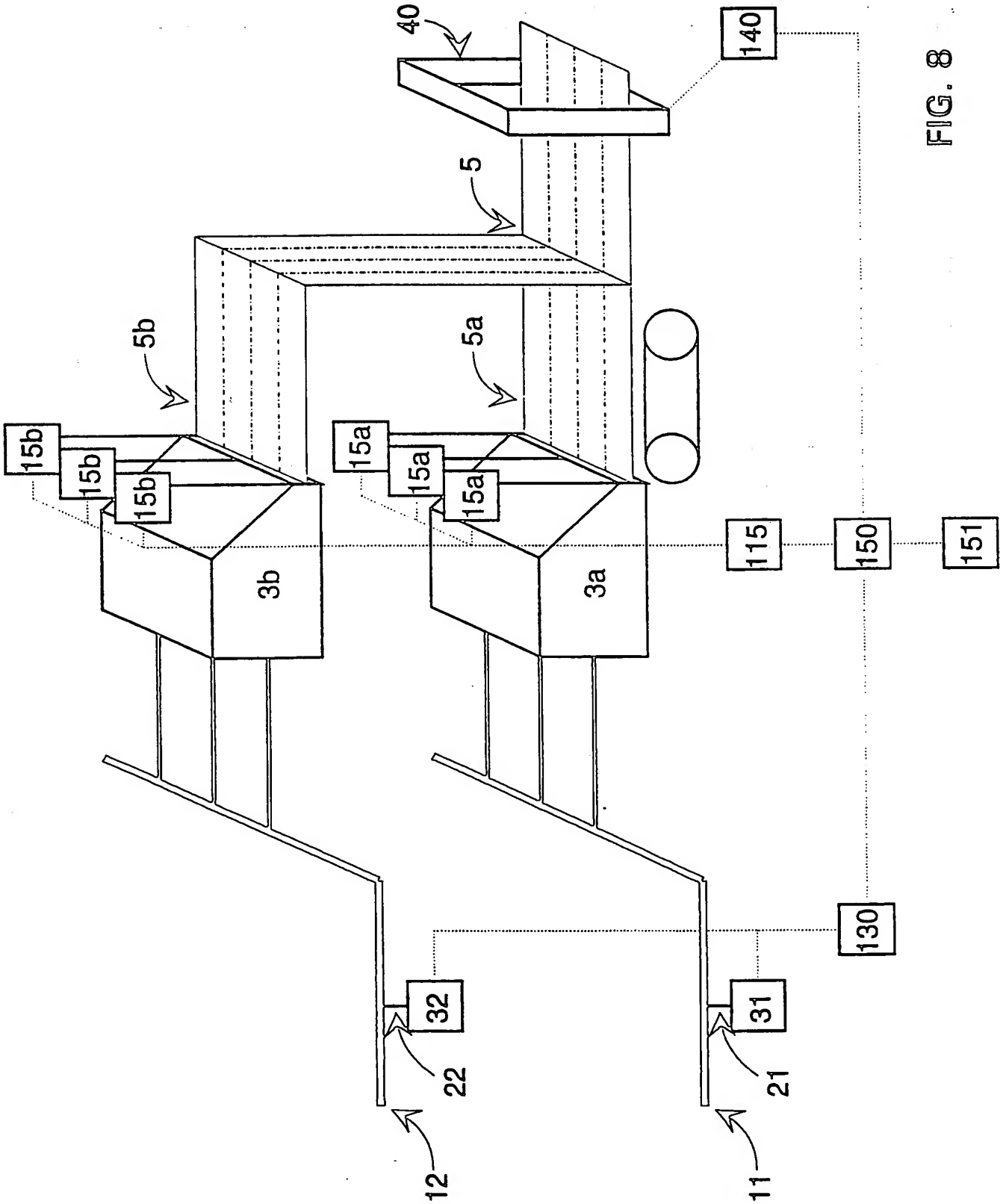
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FIG. 8

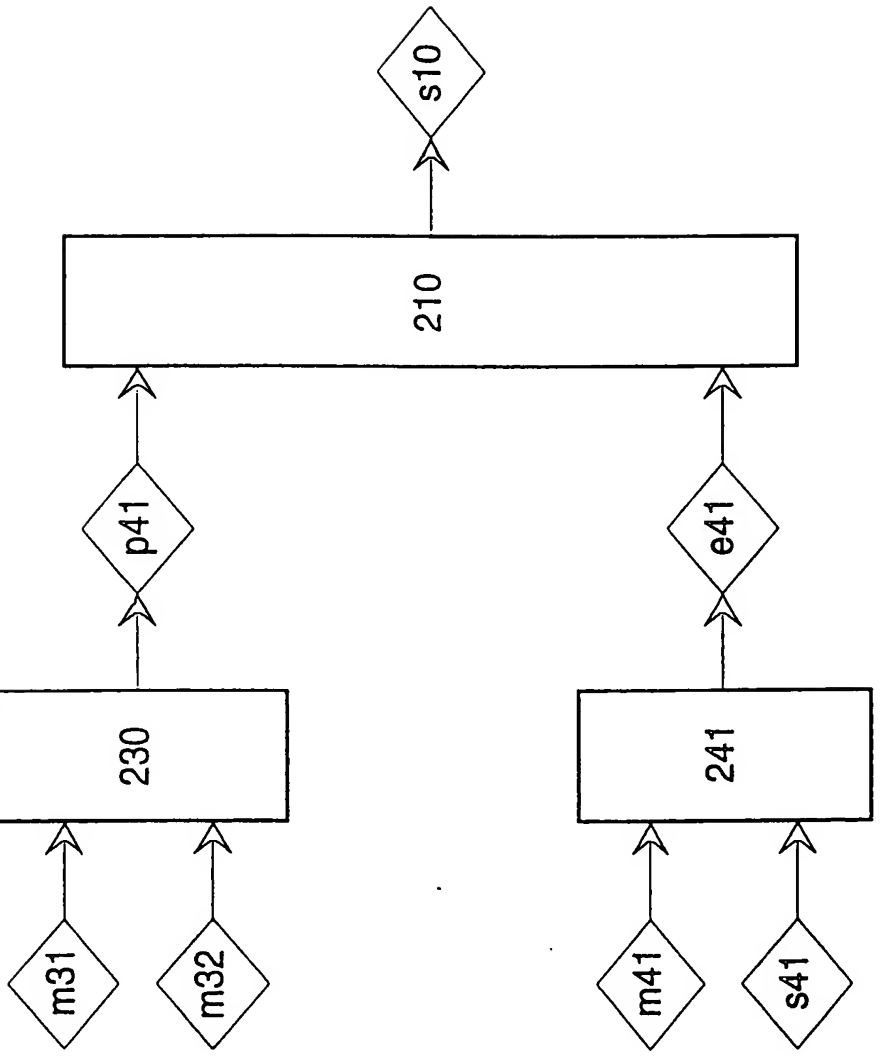


FIG. 9

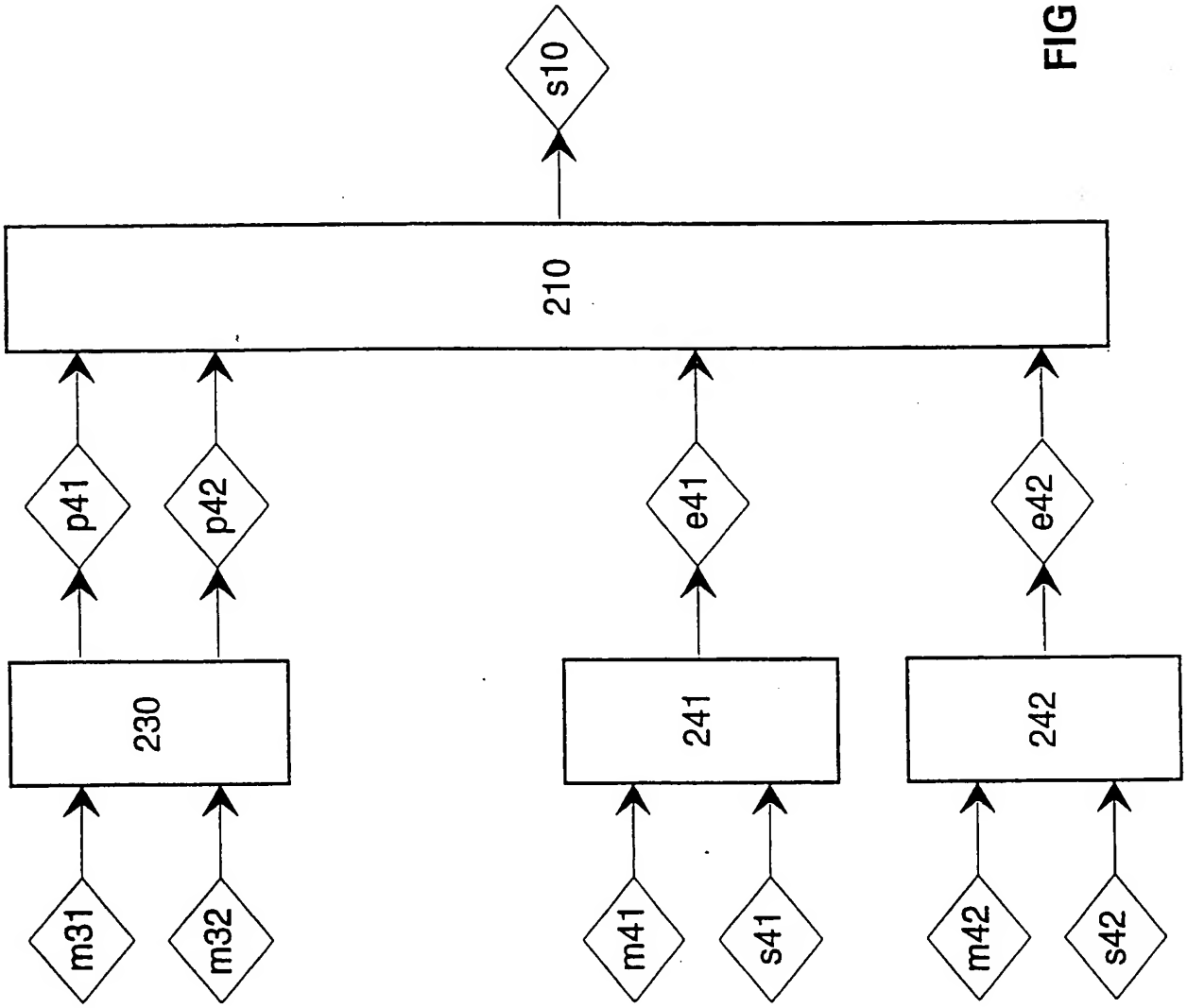


FIG. 10

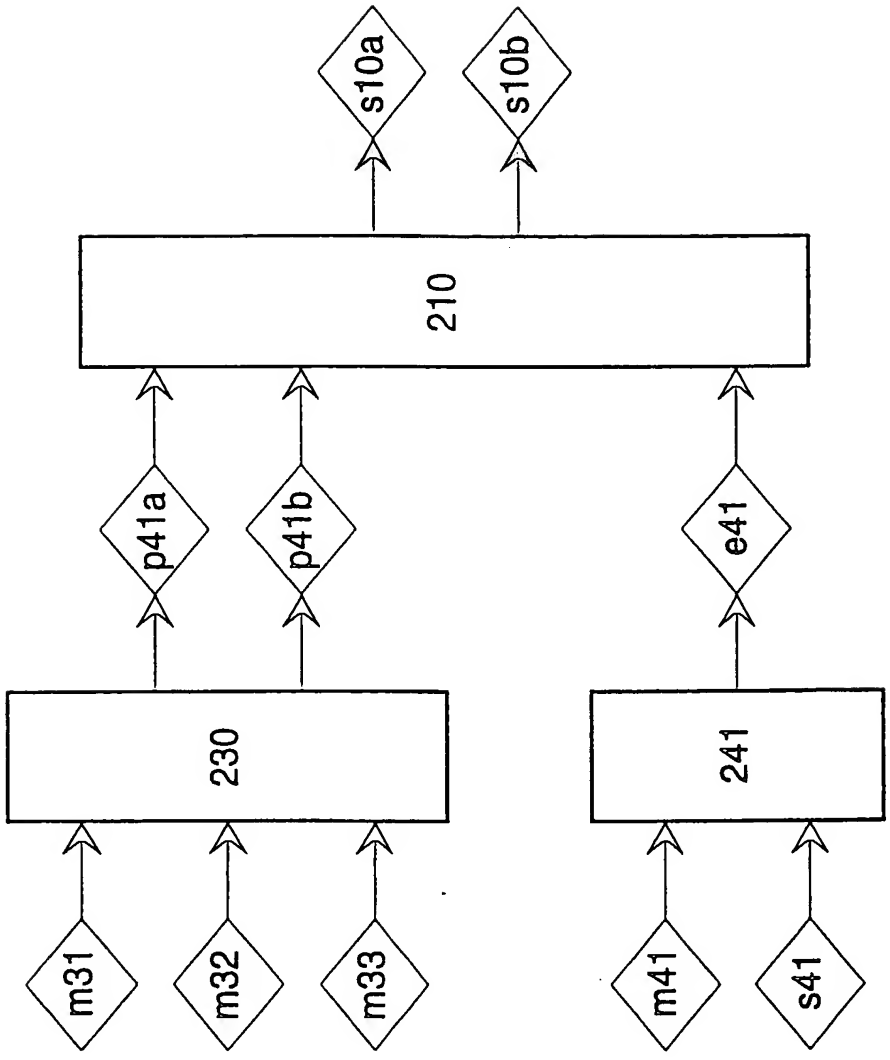


FIG. 11

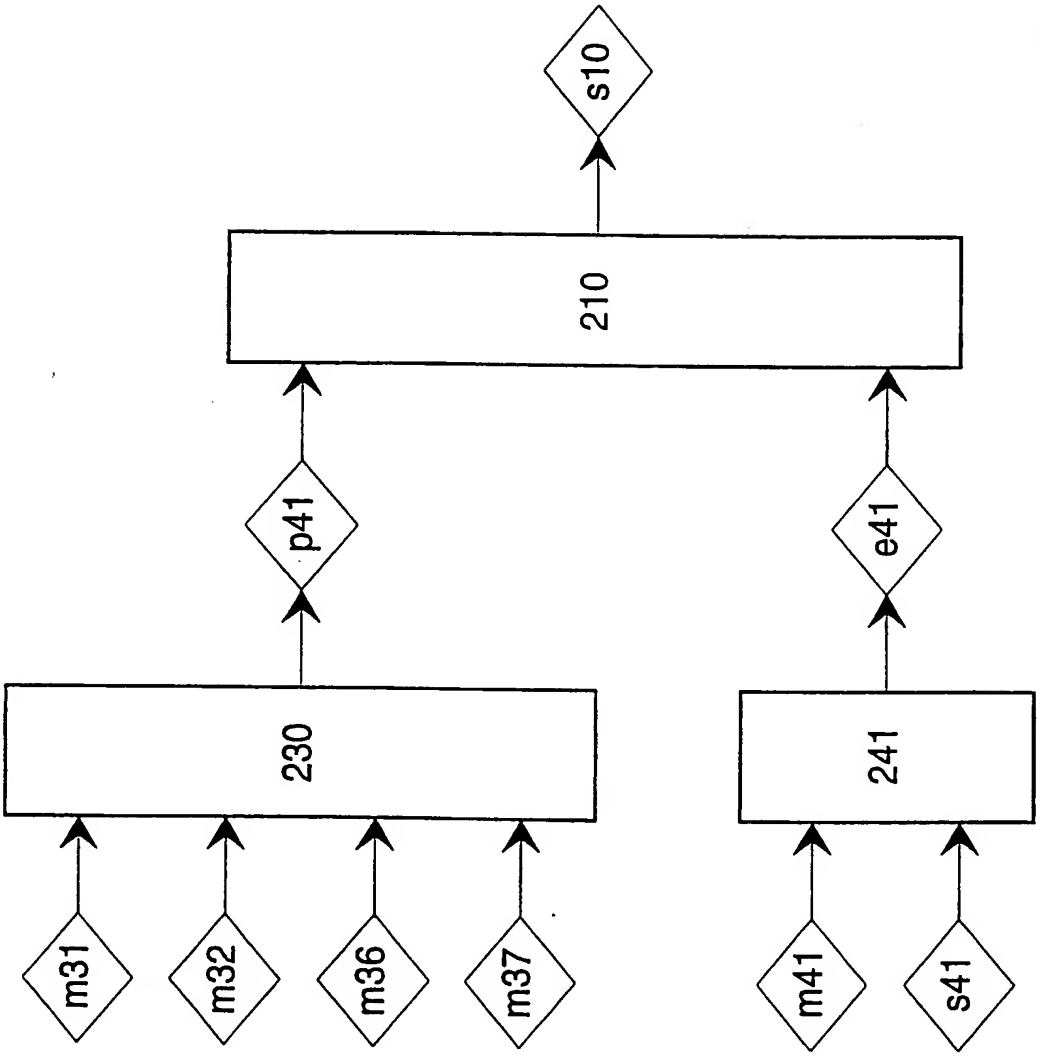


FIG. 12

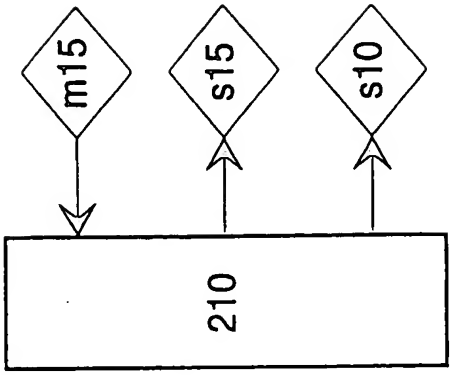


FIG. 13c

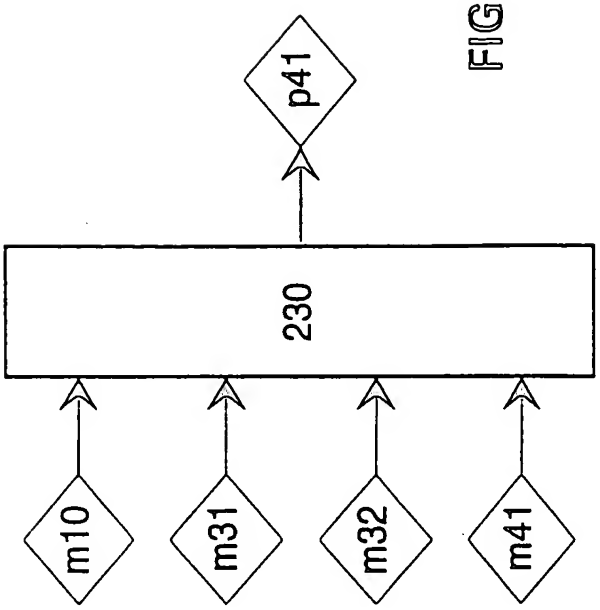


FIG. 13d

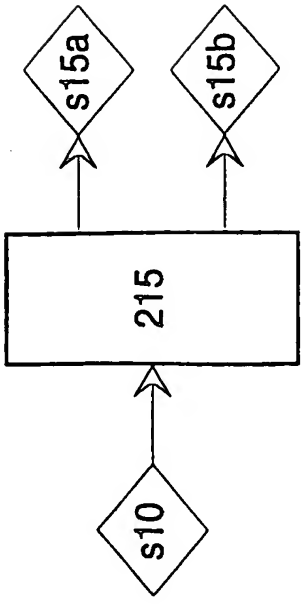
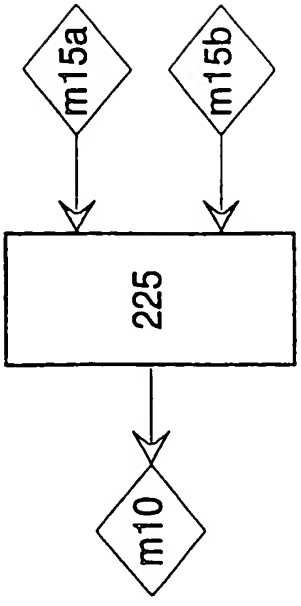


FIG. 13a



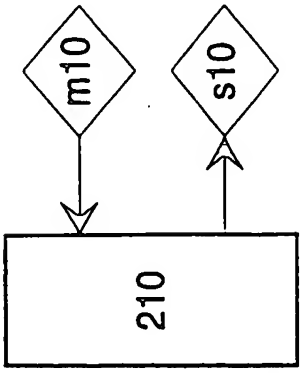


FIG. 13b

INTERNATIONAL SEARCH REPORT

International application No.
PCT/FI 98/00032

A. CLASSIFICATION OF SUBJECT MATTER

IPC6: D21F 1/02, D21F 7/06
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC6: D21F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
P,A	WO 9723839 A1 (MEASUREX CORPORATION), 3 July 1997 (03.07.97) --	1,7,17,24
A	US 5381341 A (JUHA HERRALA ET AL), 10 January 1995 (10.01.95) --	1,7,17,24
A	EP 0633352 A1 (VALMET PAPER MACHINERY INC.), 11 January 1995 (11.01.95) --	1,7,17,24
A	EP 0408894 A2 (VALMET PAPER MACHINERY INC.), 23 January 1991 (23.01.91) -- --------	1,7,17,24

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:
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"E" erlier document but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
15 May 1998	19 -05- 1998
Name and mailing address of the ISA Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Authorized officer Olov Jensén Telephone No. +46 8 782 25 00

INTERNATIONAL SEARCH REPORT

Information on patent family members

29/04/98

International application No.
PCT/FI 98/00032

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 9723839 A1	03/07/97	NONE	
US 5381341 A	10/01/95	AT 118845 T	15/03/95
		CA 2018114 A	01/12/90
		DE 69017083 D,T	20/07/95
		EP 0401188 A,B	05/12/90
		SE 0401188 T3	
		FI 85731 B,C	14/02/92
		FI 892670 A	02/12/90
EP 0633352 A1	11/01/95	CA 2127155 A	02/01/95
		FI 92229 B,C	30/06/94
		FI 933029 D	00/00/00
		US 5674363 A	07/10/97
EP 0408894 A2	23/01/91	SE 0408894 T3	
		AT 137827 T	15/05/96
		CA 2021355 A,C	18/01/91
		DE 69026873 D,T	31/10/96
		FI 81848 B	31/08/90
		FI 893461 A	31/08/90